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ABSTRACT

The documents that constitute this report include essays by those who direct the National Research Council (NRC), its units, and its parent institutions, as well as descriptions of a few of the study projects under way in 1976. Eight divisions of the NRC report on various aspects of their goals and projects: the Assembly of Engineering, the Assembly of Life Sciences, the Assembly of Behavioral and Social Sciences, the Assembly of Mathematical and Physical Sciences, the Commission on Natural Resources, the Commission on Sociotechnical Systems, the Commission on Human Resources, and the Commission on International Relations. The Institute of Medicine reports on study projects relating to primary health care and a national health policy. Appendices include guidelines for review of reports, and reports of the NRC published in 1975. (MH)

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The National Research Council in 1976

Current Issues and Studies

U.S. DEPARTMENT OF HEALTH,
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Preface

The National Research Council is, by any standard, a sizable enterprise, with some 7,400 men and women serving on some 940 committees and subcommittees, panels and subpanels, boards and *ad hoc* study groups. Given that breadth, this initial effort to open a window into the operating Research Council must necessarily provide only a narrow view.

Nevertheless, the hope is that this report—and those to follow each year—will be truly revealing of the nature of the institution, the issues that concern and often trouble its officers, and the ultimate goals of its several parts. The documents that constitute this report include essays by those who direct the National Research Council, its units, and its parent institutions, as well as descriptions of a few of the study projects under way in 1976.

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I

NATIONAL RESEARCH COUNCIL

PHILIP HANDLER
Chairman, Governing Board of the National Research Council; *President*, National Academy of Sciences

1

Scientific Volunteers in the National Service

The realization that science—understanding gained by deliberate inquiry—can be used to improve man's condition has been significant to Western civilization for only a few hundred years. With that realization, our species accepted responsibility for its destiny; the question now is whether we can manage the world thus fashioned.

The three decades after World War II have been a time when monumental leaps of understanding were achieved in all scientific disciplines. Profound insights, hard won by disciplined minds, illuminated the nature of the atomic nucleus and of the cosmos and revealed the forces that shape the earth's surface, the molecular nature of cellular life, and the wondrous subtleties and complexities of life in higher plants and animals. Lively imagination and rigorous treatment of evidence have permitted reconstruction, at least in outline, of the historical evolution of the universe, of planet Earth, and of life.

Imperative to this enormous success was enlightened acceptance by government of its role as financial patron of science. The progress of science and, hence, the national interest require that the best research by the best investigators be identified and supported, that priorities for future fundamental scientific research be determined by the logic of the scientific disciplines themselves. The political process is indispensable to the allocation of resources for these purposes and to the setting of broad research goals and priorities, but that process should not be injected into the selection of any but the largest and most expensive research projects.

It would seem self evident that priorities for federal programs of applied research and development should arise out of broad planning for the relevant missions of the responsible federal agencies. And, indeed, when the federal government is itself the intended user of the research results, e.g., for defense or for the space program, the role of the government as supporter of applied research is readily understood, as it is for agriculture, some aspects of environmental protection, and medicine. Unfortunately, the role of government in support of research that may enable development and deployment of new technologies to sustain and enrich the civilian economy is not equally clear. Nevertheless, such a role must rapidly evolve if there is to be a deterrent to the continuing erosion, in the world market, of the American lead in introducing innovative technologies.

The extraordinary expansion of fundamental scientific understanding paralleled and, indeed, nourished a rich outpouring of new technologies. Some of these, such as nitrogen fertilizer and the automobile, were the result of successive incremental improvements in established technologies. Rarer but more dramatic in their impact have been new technologies—transistors, lasers, digital computers, herbicides, immunosuppressive agents come to mind—that arose out of totally new and fundamental insights and that created their own places in the market. Of course, most new products resulted from both processes. In myriad ways, this cornucopia of technology eased, lengthened, and enriched the lives of the peoples of the industrialized nations while contributing to a metamorphosis of their societies. But the time for simply enjoying these enormous boons was extremely brief and was rapidly invaded by heightened awareness of unresolved ancient problems and of new problems, apparently engendered by our own technological successes.

It has been aptly said that the time in which we live is "a hinge of history," a moment when the veil has been removed from our view of the past and when we can also begin to discern the forces that must shape the future. A bewildering array of problems and questions compete for public attention and government action. However, the extent and intensity of concern is not always proportional to the magnitude of the problem.

However disturbing they may seem, least troublesome, *for the long term,* will be those concerns arising from physical or biological side effects of a useful technology—e.g., a toxic food additive, a cancer-inducing drug, or air polluted by the exhaust emissions from automobiles, trucks, buses, and fossil-fueled power plants. In due course, wise regulation will surely compel the development of economic and effective controls that will adequately protect man and the environment against such situations.

More perplexing are the unforeseen, undesirable *social* consequences of technologies that are judged to be technically successful. Consider those technologies that, collectively, have reduced the fraction of the total labor force required to feed, clothe, and house the rest of us. These have also eliminated most unskilled jobs, decreased the sense of job satisfaction, accelerated urbanization, and, thus, contributed to such powerful social stresses as increasing crime and deterioration of education and other public services. Whereas new technologies may help deal with these stresses, it is unlikely that they can be successfully managed by a return to older, less efficient technologies. However appealing the dream, we cannot set back the technological clock. But our society must take firm hold of the seemingly inexorable, unguided nature of technological change, apparently endowed with a dynamic independent of deliberate human design.

At a yet more profound level of concern lies that set of relationships occasionally called the "problematique": growth of the worldwide human population at 2 percent per year; the increasing numbers of individuals in the developing nations whose lives are limited by their nutritional status; the increasing child death rate from starvation; the disparity between worldwide agricultural production and worldwide food requirements; the limited worldwide reserves of combustible fossil fuels and of uranium-235 set against inevitable future increases in the cost of energy; limited reserves of a host of other minerals essential to the operation of the worldwide economy; and the ever-increasing burden upon the environment resulting from human activities. The "problematique" defines the human condition. It is put in perspective by the realization that even if all the land in the world now in cultivation were managed by the standards of American agriculture, protein production per capita, worldwide, would still be little more than one-half that now available to the average American. But the effort to do so would exhaust world supplies of petroleum and natural gas within a decade. The amount of land in cultivation, and, therefore, food production, could be further increased by large-scale irrigation—but only at the cost of yet more rapidly depleted fossil fuel stocks and the risk of unpredictable climate changes.

Confrontation with these brutal realities will concern governments for the indefinite future. The domestic tensions so generated within all nations already contribute significantly to the accelerating disappearance of democracy around the globe. The international tensions generated by the pressures of the problematique are heightened by the new aspirations of the citizens of the Third World, reinforcing those tensions that already threaten one day to detonate the world stockpile of weapons. Hence, the concern for the ever-increasing sophistication of conventional (*sic!*) weapons. Hence, the concern for the growing nuclear arsenals of the superpowers, and for the increasing number of nations that now have nuclear weapons. Hence, the concern for the proliferation of nuclear power technologies, including those for the separation of uranium-235 from its isotopes, which is certain to expand the number of additional nations that may be expected to possess nuclear weapons.

Much attention has been attracted by mathematical models of the future world economy, models that suggest that immense catastrophe must be the outcome of simple extensions of current world trends. And if there is no thoughtful, calculated, major intervention, that may prove to be true. For the present, however, a counsel of despair seems premature. Conceivably, the principal problems have been recognized in sufficient time; imaginative application of human talent and of the great body of knowledge already in hand or obtainable by the scientific method may yet permit realization of the golden dreams of a better tomorrow that have stirred in man's brain since Prometheus stole fire from the gods.

The immense political problem for nations is to maintain a stable society with a full measure of education, equity, social justice, and individual freedom while charting a course to a highly technological world in which human beings, in equilibrium with their environment, can enjoy rich, meaningful lives.

Science and science-based technology have lengthened, eased, and enriched most human lives, concomitantly exchanging the hardships and hazards of the ignorant, primitive human condition for the more complex hazards that must now be confronted. To cope with these problems we have greatly strengthened resources of trained manpower and the wealth of new knowledge provided by the scientific endeavor of the last few decades. Whilst science may well have contributed to the decreased manageability of the current world, few would disagree that science, the very best of science, is imperative to the task of establishing a viable, stable balance between a lively, decent, human civilization and the resources of planet Earth.

Accordingly, government programs of research and development, government policies for the wise utilization of technology, and government participation in the international relationships that will be fashioned by the realities inherent in the problematique must increasingly rest on sound, analytical studies performed by persons highly knowledgeable with respect to science and technology. The challenge is to enable the government to draw continually upon the expertise and intellectual resources distributed through other institutional components of our pluralistic society, but without unduly altering or controlling those components. That challenge must be the principal charge to the National Research Council.

THE NATIONAL ACADEMY OF SCIENCES

As the American scientific and technological enterprises grew, their involvement with government necessarily increased—for example, in exploring the continent and mapping its resources, arming the military forces, and safeguarding the public health. The proliferation of science-based federal agencies is evidence that support of scientific research and application of its results are, increasingly, a principal business of government. Accordingly, the Congress and the executive branch have long acknowledged the need for advice from competent scientists in order to assure the quality of the many decisions that must be made in giving direction to these diverse technical enterprises. A major step toward meeting that need was taken, more than half the life of the Republic ago, when President Lincoln signed the Congressional Act that became the charter of the National Academy of Sciences. Part of that Act follows:

SEC. 2. . . . and the said corporation hereby constituted shall have power to make its own organization, including its constitution, bylaws, and rules and regulations; . . .; to provide for the election of foreign and domestic members, the division into classes, and all other matters needful or usual in such institutions and to report the same to Congress.

SEC. 3. . . . and the Academy shall, whenever called upon by any department of the Government, investigate, examine, experiment, and report upon any subject of science or art, the actual expense of such investigations, examinations, experiments and reports to be paid from appropriations which may be made for the purpose, but the Academy shall receive no compensation whatever for any services to the Government of the United States.

GALUSHA A. GROW
Speaker of the House of Representatives
SOLOMON FOOT
President of the Senate pro tempore

Approved March 3, 1863
ABRAHAM LINCOLN, *President*

With those words, the National Academy of Sciences was set upon the path of public service. As an Academy, a principal function, under Section 2, has been to recognize, by election to membership, those individuals who have made unusually distinguished contributions to scientific understanding or its application. The principal concern of the Academy is the dispassionate pursuit of truth, a pursuit which the Academy shares with universities. The obligation upon the Academy is to forward the progress of the scientific endeavor by diverse means and to assure that scientific understanding and technical capability are impartially utilized for the common weal, an obligation shared with the government.

Over the succeeding century a small fraction of all natural and social scientists, physicians, and engineers has been honored by election to membership. Since World War I, the preponderance of those elected have been natural scientists engaged in fundamental research, with lesser numbers of individuals whose careers were in applied research or development, as in engineering, agriculture, or medicine. The need for competent social scientists, clinical investigators, and engineers to help manage the affairs of the National Research Council resulted in the decision, in 1972, to elect to Academy membership significantly increased numbers of such individuals. The disciplines represented within the Academy are now so diverse that the membership is organized into twenty-five disciplinary sections in order to facilitate the election process. However, in general, the values of students of the natural sciences still predominate in shaping Academy affairs. Indeed, the social scientists, clinicians, and engineers elected to membership are frequently those whose interests, attitudes, and intellectual accomplishments have been rather like those of natural scientists and mathematicians. Inevitably, the election process has at times overlooked scientists whom history will judge incontrovertibly to have deserved election. In the main, however, the process works reasonably well; over the years, members of the Academy have most certainly provided a very large share of the intellectual leadership of the American scientific endeavor.

THE NATIONAL RESEARCH COUNCIL

The National Academy of Sciences exists *sui generis*. It is a private institution with a congressional charter that grants to the government privileged access to the capabilities of the Academy complex; conversely, although a private body, the NAS, by tradition, has a somewhat special relationship to the government.

Many advisory bodies have been created by individual government agencies that they then serve; each such advisory body, when it so functions, is itself part of government even though its members are drawn from private life. In contrast, the Congress created the Academy as an entity to exist at a remove from government, not to serve one agency, but "any department of the government. . . ." Accordingly, the Academy has evolved an organization and a set of procedures by which the intellectual resources of the entire national scientific community are made available to the processes of government, yet remain independent of the government and of its agents while offering knowledge and technical judgment in the public interest.

Between 1863 and the outbreak of World War I, requests to the Academy from the government, under the terms of Section 3 of the Charter, were significant but rather infrequent. Recognizing the likelihood of an increased level of such activities upon the entry of the United States into World War I, and desiring to serve more efficiently and effectively during that crisis, the Academy brought into being an organizational arrangement called the National Research Council (the NRC):

> . . . to promote research in the mathematical, physical, and biological sciences and in the application of these sciences to engineering, agriculture, medicine, and other useful arts, with the objective of increasing knowledge, strengthening the national defense, and of contributing in other ways to the public welfare. . . . The National Research Council shall serve, whenever possible and desirable, as the principal operating agency of the National Academy of Sciences, furnishing professional and research advice to governmental and other organizations and administering such funds that may be entrusted to it.

On May 11, 1918, by Executive Order Number 2859, President Wilson recognized the outstanding performance of the NRC during the war and requested that the Academy perpetuate the NRC. Today, the NRC remains the principal mechanism by which the institution performs those services mandated in Section 3 of the Academy Charter.

For most of its history, the NRC was a membership organization, consisting of the representatives designated by a multitude of affiliated scientific and professional societies, together with a limited number of representatives of appropriate federal agencies. The members were organized into divisions, each of essentially disciplinary character: physical sciences, mathematical sciences, chemistry and chemical technology, medical sciences, earth sciences, biology and agriculture, behavioral sciences, engineering.

Each study project undertaken by a given division, usually in response to a request from a federal agency, was the responsibility of either a standing committee or an *ad hoc* committee appointed for the purpose. Reports from the "NAS/NRC" were the reports of those committees.

The genius of the NRC idea was that it permitted the Academy to tap for service those scientists, anywhere in the nation, most competent and knowledgeable with respect to the particular problem at hand. At any given time, only a small fraction of the thousands of scientists, physicians, and engineers so serving were members of the Academy; yet this arrangement, which placed the entire national technical community at the
10 service of the federal government, was at all times guided by the scientific standards of the Academy membership.

The National Research Council was particularly instrumental in assisting the government in organizing the emergency scientific and technical efforts in both world wars. After the second war, involvement of the government with technical matters expanded and deepened; national expenditures for research and development climbed. Concomitantly, the government's appetite for technical advice grew rapidly, and a host of advisory mechanisms was invented to satisfy that need.

Those mechanisms continue to evolve. Thus, congressional committees have traditionally utilized the hearing process as their major means of gathering information and advice on technical matters. But the growing sense of the inadequacy of this mechanism, *for this purpose*, contributed in large measure to the recent creation by the Congress of its own Office of Technology Assessment. Within the executive branch, advisory mechanisms richly proliferated. Yet, despite the extent and diversity of their advisory structures, government agencies have increasingly turned to the "NAS/NRC" for assistance.

Unlike the circumstances of the distinguished Academies of the European nations, no provision was made by the Congress for a minimal financial subsidy of the Academy simply to assure that it is in being and available to respond "whenever called upon." Nor, when the NRC was perpetuated by the Academy at the request of President Wilson, were any funds provided to assure that the NRC would, indeed, continue to exist. Upon receiving a request from a government agency, the Academy responds by making a "proposal" to that agency. That proposal may accept or modify the originally posed question; it must propose a budget and describe how, in general, the NRC will go about the study project. If the proposal is accepted by the agency, a contract for cost reimbursement is then written. The contract provides for neither a fee for service for the Academy nor fees for service by the volunteers who serve on the NRC committees.

Over the years, the generosity of a number of donors, particularly major philanthropic foundations, has provided an endowment that now yields an annual income of which no more than about $250,000 is potentially available for support of individual study projects in the style of the NRC. Hence, to undertake a new project on its own initiative, an NRC committee has usually had first to seek external funding—a severe handicap to a volunteer group. For lack of a base of stable funding, NRC committees have operated largely in a responsive mode, undertaking studies on the request of the government; only rarely has a committee been able to undertake, on its own initiative, a large, comprehensive study of a major question.

The evolution of the National Research Council and, particularly, its recent reorganization have been conditioned by the presence at the Academy of two other membership organizations. In 1964 the Council of the NAS created, as a semi-autonomous body within the corporate entity, the National Academy of Engineering (NAE). The NAS has traditionally elected to membership engineers of unusual distinction in the design and development of innovative technologies, and numerous engineers have participated in the work of the Division of Engineering of the NRC. Election to membership in the NAE is based on a broader interpretation of the role of engineers in American society than that utilized in considering candidates for election to membership in the NAS.

The programs of the NRC's Division of Medical Sciences were, traditionally, focused on the scientific basis for improving the capability of medicine to prevent or alleviate disease. Recognizing the need for an organizational entity designed to perform intensive analyses of the problems confronted by the nation in providing medical care to its citizens and to assist in the development of appropriate national policies, the Institute of Medicine (IOM) was brought into being by the Council of the NAS in 1970. The diversified membership of the IOM includes not only physicians but also practitioners of the many other disciplines that can contribute to the formulation of health care policy.

Reorganization of the National Research Council

The NRC was reorganized in 1973 for several reasons:

1. To provide an effective governance in which the Councils of the NAS, the NAE, and the IOM could all participate.

2. To terminate the concept of "membership" in the NRC. Liaison would still be maintained with scientific and professional societies, but the latter would no longer name representatives to be responsible for the work of the NRC, a long outmoded concept. Instead, there would be markedly increased participation by members of the NAS, the NAE, and the IOM in the governance and work of the NRC.

3. To strengthen the major organizational subunits of the NRC and to transfer to them much of the responsibility for initiatives and decisions concerning their agenda.

4. To generate organizational structures appropriate to the conduct of large multidisciplinary study projects.

5. To facilitate the institution of a set of quality controls for the entire enterprise.

The major administrative units of the restructured NRC are now as follows:

Assembly of Behavioral and Social Sciences
Assembly of Engineering
Assembly of Life Sciences
Assembly of Mathematical and Physical Sciences
Commission on Human Resources
Commission on International Relations
Commission on Natural Resources
Commission on Sociotechnical Systems

The Assemblies, like their predecessor Divisions, are organized along disciplinary lines. They are intended to promote progress in their constituent disciplines and to address those societal problems that can usefully be considered along disciplinary lines. Each Assembly has an executive committee of 15–20 members, of whom at least half are drawn from the appropriate sections of the NAS or from the NAE. The President of the NAE is Chairman of the Assembly of Engineering; the Chairmen of the other Assemblies are members of the NAS, appointed by the President of the NAS and approved by the NAS Council.

The creation of the NRC Commissions recognizes that many of the problems of American society cannot be neatly placed into disciplinary packages. The larger problems that increasingly engage the NRC—be they research needs for increasing food production and alleviating malnutrition, more effective ways to manage our environment, or appraisal of the future of nuclear energy—can be usefully addressed only by multidisciplinary bodies, i.e., mixtures of natural and social scientists, engineers, physicians, attorneys, industrialists, and others. Each Commission, therefore, consists of 15–20 members, at least half of whom are drawn from the memberships of the NAS, the NAE, and the IOM, and comprising a mix of disciplines appropriate to the work of the specific Commission.

The Institute of Medicine is unique in this structure. It is both an elected membership organization and part of the advisory apparatus of the Academy complex. The elected Council of the IOM plays the same decision-making role as the Commissions, subject to approval by the Governing Board of the NRC.

The Governing Board has thirteen members—seven from the NAS Council, four from the NAE Council, and two from the IOM Council. The NAS president is Chairman of the Governing Board, and the NAE president is the Vice Chairman. (Appendix C lists the members of the Governing Board and the members of the various Councils.)

About 50,000 persons have participated in voluntary activity within the NRC in the years since World War II. Together with the memberships of the NAS, the NAE, and the IOM and the institutional staff, they constitute an elaborate, sophisticated network for the identification of those individuals with the special talents, competence, insight, and wisdom that may be required for the future advisory work of the NRC. A principal purpose of this first annual report of the National Research Council is to indicate to the American people and to the legislative and executive branches of our federal government that this carefully constructed, intellectually powerful consultative arrangement, unique in all the world, stands ready to be of service ". . . whenever called upon. . . ."

Some Statistics

During the year ending on June 30, 1975, there were 560 committees, boards, and commissions within the National Research Council; their functioning required the existence of an additional 378 panels, subcommittees, and other subgroups. Approximately one-sixth of these committees and subunits had been brought into being during the previous year, replacing a slightly smaller number that had completed their tasks and were discharged during the same period. All told, nearly 7,400 different individuals served in approximately 9,325 "slots" within all of the units of the National Research Council during that year.

Members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine constitute 90 of the 133 persons serving on the Executive Committees of the Assemblies and on the Commissions. As of June 30, 1975, 195 members of the NAS, the NAE, or the IOM were serving in the report review system, which exists apart from the structure of the NRC proper. In all, a total of 611 members of the NAS, the NAE, or the IOM—approximately one-third of their membership—served the NRC during the year.

The critical unit of the National Research Council is the individual serving on a study committee. The contributions of the 50,000 volunteers who have served the NRC in the last three decades constitute a huge, loving, generous gift to our country.

What Questions Shall Be Addressed?

Each year every Assembly and Commission submits to the NRC Governing Board a program plan for the work it expects to undertake in the coming 12 months. In developing that plan, the Assembly or Commission must evaluate the totality of its activities and examine whether the committees of that unit are addressing the most important relevant questions. In the same light, the program plan is reviewed by the Governing Board.

Most study projects undertaken by the NRC have been engendered by specific requests from agencies of the executive branch, or increasingly, by the Congress. The staff of the NRC has usually had opportunity, by negotiation with government officials, to assure that the right question has been asked and stated in acceptable form. Occasionally, however, an NRC committee has been frustrated by a request to address a question that seems too narrow or an insufficient fragment of a total problem.

With the newly reorganized NRC now in place, it is expected that an increasing fraction of its activity will be self-generated. However, it remains to be seen whether the necessary funding can be obtained when projected costs of a comprehensive study of some sharply focused major question are comparable to, for example, those of the current studies of world food and nutrition (page 170) or of the future of nuclear energy (page 29). Yet, conduct of such studies, addressed to long-term problems that must be managed on a time scale much longer than that of the normal political process, should be a principal role of the NRC, as distinct from that of in-house advisory mechanisms of the government.

Who Serves on NRC Study Committees?

The role of an NRC committee is to clarify and narrow the issues whenever possible, to bring forward all relevant information, to appraise existing questions and raise new ones, to formulate necessary research, and to indicate available options and their consequences. In gathering a committee to undertake such a task, access to the entire national technical community is the principal asset of the NRC. An invitation to serve on an NRC committee is generally welcomed as a mark of high distinction.

Committee appointments are generally proposed by the chairman of the Commission or Assembly in consultation with members of his unit and frequently with other units of the NRC. The proposed slate of committee members is reviewed by a special office within the Executive Office of the National Research Council to ascertain that

- Appropriate sources, within and outside the NRC, have been consulted concerning the selections
- The proposed individuals are indeed highly qualified to address their common task
- The required areas of competence are appropriately represented
- There is meaningful geographical balance
- Within the entire NRC, there is steadily increasing utilization of women and members of minority groups
- Each year, more young scientists are introduced into such committee work

The same office is responsible for oversight of the process whereby the institution attempts to avoid improper intrusion of bias into the deliberations of its committees. The primary instrument utilized for this purpose is a form entitled "On Potential Sources of Bias," a copy of which is provided as Appendix A. Whenever the nature of the subject matter suggests the desirability of utilizing this form, all members of the committee are requested to complete it. The appointment process is regarded as complete only after it has been determined that the proposed appointments would not prejudice the outcome of the committee's efforts.

Instances of conflict in consequence of personal financial interests have been extremely rare. The problem of "bias" can be much more subtle, involving, for example, an individual's public stance on the subject to be considered. Of course, opinion tends to divide on major questions; and, occasionally, the scientific community may be seriously polarized as it has been, for example, with respect to the future of nuclear energy. It has seemed wise to avoid appointments of individuals who have *publicly* taken extreme positions, and the "bias form" helps us to accomplish that. However, attitudes not publicly expressed are not revealed by these forms. It is the task of the committee chairman and of the NRC staff to become aware of these attitudes and to ensure that the committee is adequately balanced so that its judgment will be free of any systematic nonobjective influence.

In a matter of public controversy, an NRC report will usually constitute but one element in public decision making; the diverse attitudes and value system of our complex society must have full opportunity to affect decision making *after* the technical report is available.

It is occasionally argued that the reports of NRC committees would be "more credible" were there "representatives of the public" on the committees. However, NRC reports are *technical* reports, and NRC committees consist largely of technically trained people with competence relevant to the subject matter. The reports are intended to be free of values, except for that one value upon which there is absolute insistence: rigorous adherence to the truth, insofar as truth can be determined.

The Review Process

The NRC is not a collegial organization. When the NRC agrees to a task, the institution, collectively, accepts responsibility for the resultant report. This responsibility is exercised in the discussions that determine the actual question to be addressed, in the care with which the study committee is constructed, and in the work of the staff in bringing all necessary materials to the committee's attention. When the committee's work is complete, it is imperative that the institution satisfy itself of the quality of the report. This is accomplished by a review procedure, the standards for which are established by the Report Review Committee. Each Commission or executive committee of an Assembly must satisfy itself that its own reports meet those standards. In addition, at the discretion of the Report Review Committee, about 15 percent of all reports are examined by an *ad hoc* panel of reviewers especially assigned by the Report Review Committee from among a standing panel of members of the NAS, the NAE, and the IOM. Such a second review is made when the subject is a matter of public interest or controversy, when the report contains significant recommendations for public policy, when it is felt that the report should be reviewed by persons whose disciplinary background and interests differ markedly from those of the authoring committee, or when the Report Review Committee is concerned, for any reason, about the quality of the report. (See Appendix B for instructions given to reviewers by the Report Review Committee.)

This second review normally results in a rather detailed commentary to which the authoring committee is obliged to respond. The report may be released only after satisfactory completion of this process. This review system has been in place for several years. Although it is not foolproof, it does work very well. We are unaware of any other organization that goes to equal lengths to assure the quality of comparable reports.

Public Access

In 1975, by formal adoption of an institution-wide policy, the process by which NRC study projects are conducted was opened to the public in several ways:

- When a new project committee is established to address a matter of public controversy, that committee is encouraged to hold public hearings for the receipt of relevant information and views.
- After a report has passed through the normal review procedures, copies may be made available to interested, knowledgeable individuals and organizations, and a special public meeting may be convened for discussion of the report and questioning of the authoring committee. A summary of the proceedings of this meeting will become part of the public record.
- Other than the few reports classified for security reasons, all reports become public documents shortly after their transmittal to the requesting agency. At that time, a file containing copies of documents and information made available to the committee during the course of its work will be opened to public inspection.

Advice in "Real Time"

The advice transmitted by the institution to a requesting federal agency is generally presented in a formal report that can then be judged on its merit by the agency and by the interested public. A principal purpose of the Federal Advisory Committee Act was to eliminate opportunities for unmonitored advice to be privately given to government officials by formally constituted committees, with no record available either of the process or of the advice given. Although that law is not applicable to the Academy as a private organization, nevertheless NRC committees, also, should not tender private, confidential advice to federal agencies. Nor do they.

The NRC, *the Academy, and the Federal Government*

The National Research Council stands today as perhaps the most powerful technical advisory apparatus available to any government in the world. Yet, uniquely, the NRC is neither part of the government nor controlled by it. That independence, together with the confidence of the scientific community, constitutes the institution's greatest strength; the arrangement is uniquely American.

Over the years, there have been varying perceptions of the nature of the legal relationship between the Academy and the government. The official *Government Organization Manual* lists the Academy among a handful of "quasi-official agencies," but neither defines that relationship nor specifies its implications. Occasionally, particularly during World Wars I and II, the Academy has seemed to function as if part of the government proper. Indeed, occasionally, Academy officers have deliberately fostered that viewpoint. But a series of formal decisions has affirmed the essentially private nature of the institution. In a test of whether recent extensions of the Government Procedures Act should be applied to the Academy as "an agency of the government within the meaning and intent of the Federal Advisory Committee Act," the U.S. District Court for the District of Columbia held that the Academy does not partake of the normal properties of a government agency—having no decision-making authority, no policy-making authority and no enforcement authority—and that those laws, rules, and regulations that Congress has established to prescribe the behavior of agencies of government do not apply to the Academy.

Still, the Academy surely cannot be considered an ordinary "not for profit" corporation. The Academy's charter at once defines the nature of the institution and stipulates that its unique resources be made available on request to the government.

But the charter also stipulates that "the Academy shall receive no compensation whatever for any services to the Government of the United States." Accordingly, when the Academy was created, no funds were provided by the government to assure its minimal existence; the initial expenses were defrayed from the private pockets of the founding members. A headquarters location was provided to the Academy for sixty years by the Smithsonian Institution at no charge to the Academy. As the result of a few modest bequests and several generous grants from major philanthropic foundations, the Academy acquired its present headquarters building and an endowment, the principal of which, at this time, is only one-third the size of the annual operating budget. It is payment of the indirect costs associated with the direct costs of the study projects that provides the financial means by which the Academy assures that the NRC does indeed exist so as to be responsive to the government. Unfortunately, that somewhat precarious existence is appreciated only with difficulty and, occasionally, engenders resentment in officials both of the diverse federal agencies with which the Academy contracts to provide services and of the philanthropic foundations.

Much more rational and desirable would be a markedly larger endowment income or an annual and assured subvention analogous to endowment income, from the government to the Academy, in an amount sufficient to assure the basic existence of the National Research Council and independent of funds provided by direct contract. A government subvention of this character, to assure the stable existence of this invaluable advisory arrangement and to enable a modest level of self-initiated studies, would be acceptable only if ironclad guarantees were provided of freedom of the NRC from government control. That this is feasible is evident in the legal arrangements for various government-financed corporations. It is also suggested by the fact that the Royal Society of London and the Academies of Science of numerous European countries receive substantial annual operating subventions from their governments even in the absence of any obligation to provide advisory services of the kind available to our government through the National Research Council.

What Are the Limits to Growth of the NRC*?*

The requirement of government for advice on technical matters will continue indefinitely. That advice will flow from the NRC as well as the governmental advisory apparatus lodged in the agencies of the executive branch, in the White House itself, and in Congress. The essential resource for all these groups is the American scientific and technical community. Our experience indicates that in some problem areas a very large number of the truly useful and knowledgeable individuals have already been commandeered for NRC service. Thus, the principal limitations on the total size of the NRC are certainly (a) the size of the competent technical community available for such service and (b) the maximum size of NRC committee structure and staff compatible with the operation of the quality controls that now exist. In a general way, the entire structure could perhaps double without exhausting the capability of the scientific community and before breakdown of necessary quality controls. But, as a nonprofit organization designed only to serve the nation, there is no motivation within the Academy to seek such growth, which brings with it only additional management responsibilities.

Scope of the NRC *Program*

The diverse program of the NRC reflects the richness and variety of the national effort in science and technology as well as the complexity of contemporary American civilization. NRC committees are currently grappling with such questions as: By what approaches can one hope to decelerate the growth of the world population? How can research increase world food production? How accurate are present estimates of national and worldwide reserves of fossil fuels, uranium, and the principal minerals in the world economy? What can one reasonably say concerning the future of nuclear power?

But most committees are engaging less global, more mundane matters, such as: What is known about the toxic effects, if any, of chronic exposure to the materials in automobile emissions? Are there data that permit setting of standards of permissible concentrations of diverse chemicals in drinking water? What will BART do to the economy of the Bay

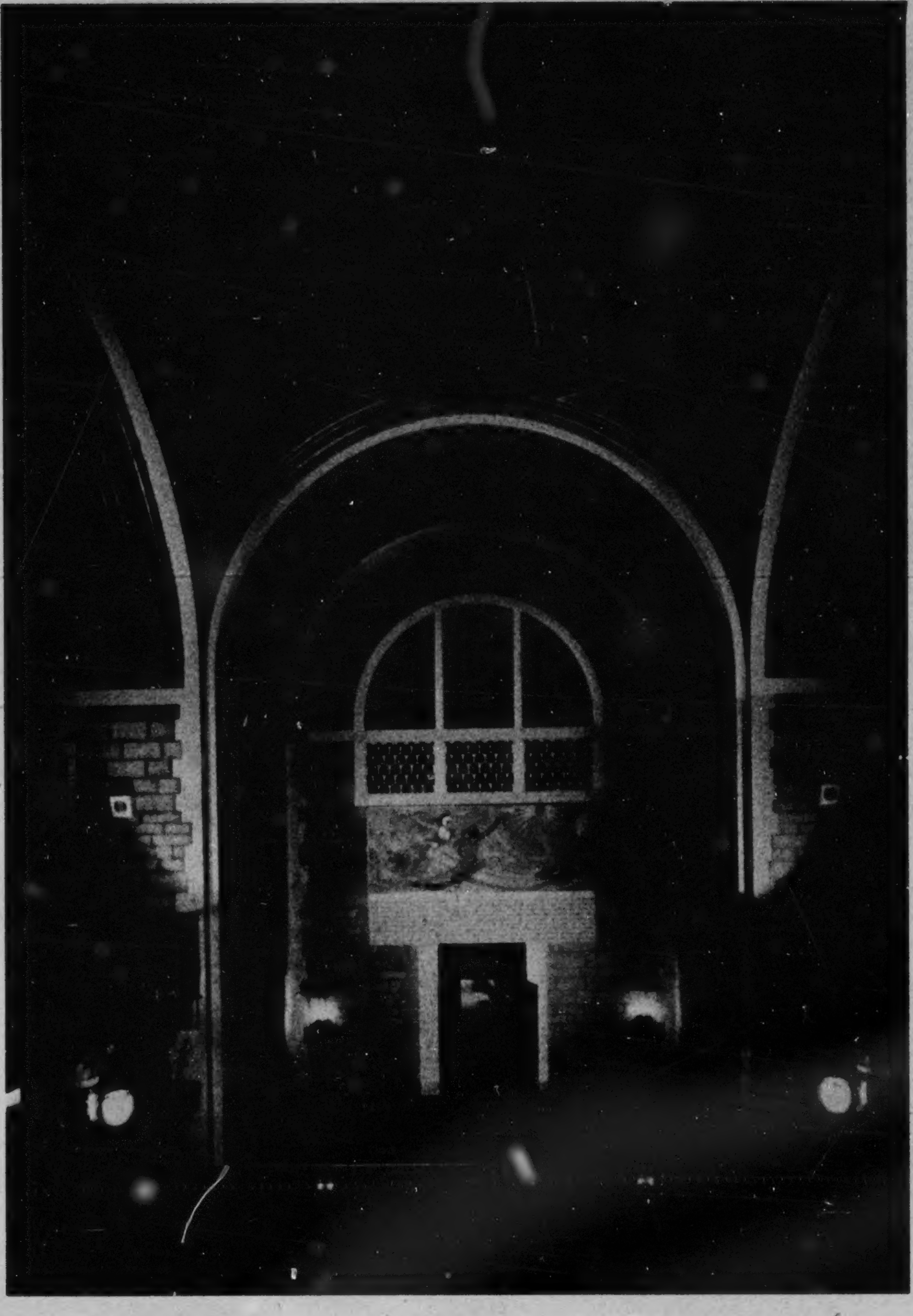
Area? Does the research program of the Veterans' Administration contribute to the quality of medical care in VA hospitals? Can one project national requirements for various types of biomedical investigators for the future? How should payments be made from Medicare to doctors working in teaching hospitals? Is more research needed on the chemistry of coal? Would manatee breeding open clogged tropical waterways while increasing the supply of "meat"? What research would improve the economy and performance of the U.S. merchant fleet?

Meanwhile, other committees select the most qualified applicants for NSF fellowships or for associateships in U.S. Government laboratories, plan the U.S. program for the International Geodynamics Project, recommend the future scientific program of the space agency, and design the organization and program of a Solar Energy Research Institute. Yet others ask whether the federal program of research on manpower programs has been sufficiently constructive; plan programs of mutual research with scientists in the countries of Eastern Europe; manage the program of scientific exchange with the People's Republic of China; plan one of various international scientific congresses; worry about the effects of continuing climatic change upon future agricultural productivity, or about the effects of halogenated hydrocarbons on the concentration of ozone in the stratosphere and what that may do to the incidence of skin cancer; consider how to build a better road or house or office or subway train—and so on and on in a bewildering, hectic, exciting kaleidoscope of problems, puzzles, controversy, discovery, learning, and service.

The NRC is a sorting machine that selects from the multitude of private and public institutions of the nation, from its many regions and cultures, an assemblage of individuals of differing talents, knowledge, and experience, calls the ensemble a "committee," and confronts it with a challenge.

In the chapters to follow, the principal officers of the institution offer their views of the scale, scope, variety, and national significance of the programs of the National Research Council.

PHILIP HANDLER



COURTLAND D. PERKINS
Vice Chairman, Governing Board of the National Research Council; *Chairman,* Assembly of Engineering; *President,* National Academy of Engineering

Assembly of Engineering

2

Engineering and the Golden Age

In several respects the 1940s through the 1960s was the golden age of science and engineering. During this period there were many spectacular advances across the full spectrum of the sciences, technology, and engineering that resulted in new industries, spectacular new systems and national programs of great significance. In science we achieved an understanding of the molecular basis of genetics, with profound consequences to life on this planet. In technology we witnessed advances in high-speed fluid mechanics, gas turbines, navigational guidance, and computation. These culminated in engineering triumphs of astonishing complexity as new science and technology fed advanced concepts in system engineering. We saw the development of nuclear weapons and power; ballistic missile systems; sophisticated space systems, both manned and unmanned; new concepts in transport aircraft; and advanced communications and information-processing systems.

The golden age was partly motivated by national fears: fears of a missile gap, a space gap, and a prestige gap. There was strong financial support for technology by the Congress with consequent effects on all levels of our society. Exponential growth of scientific and technical programs occurred in our universities, with resultant large increases in numbers of graduate students and size of faculties. This expansion attracted many of our best young minds who on graduation continued the technological momentum of the golden age.

The euphoria experienced during the golden age of science and engineering ended in the early 1970s. Certainly, a major element was national concern with the Vietnam war; but primarily it was a growing concern over the question of where the technological advances were leading the country. There were serious concerns over pollution of our environment; we were faced with the stark reality that our energy demands could not grow indefinitely if we were limited largely to fossil fuels. An economic recession and inflation brought all of these problems into high relief. It seemed that many of the great technological successes of the golden age had no immediate relationship to those real problems of the world, and as a result science, technology and engineering became suspect. Many of our brightest young minds turned away from science and engineering and looked elsewhere for challenges and new fields to conquer.

In short, there was a growing realization that the application of high technology, which was leading us into increasingly complex and costly systems, had to be constrained to fit the real needs of society as well as the real requirements of economics, energy demand, and environmental impact. Awareness of these factors gave impetus to the concept of technology assessment, which added a new and significant element to the research and development process. Today the challenge to engineering is very real, but the system designer must concern himself with societal factors of increasing complexity. This is the new dimension facing the science and engineering community. The National Academy of Sciences and the National Academy of Engineering must help in achieving national understanding of this phenomenon and in facilitating the readjustment that is necessary in the university, industry, and government.

A most disturbing aspect of this readjustment, aside from the fact already mentioned that able students are turning away from science and engineering, is an overcorrection in effort from high technology to broad societal programs. There is concern among technologists about a resultant loss in creativity and innovative spark that characterized and made possible the remarkable advances of the golden age. There must be a sensitivity to the needs and constraints of society; but this must be gained in a sensible and reasonable way that will not dampen the creative drive of our budding scientists and engineers.

An irony of our era is that technology, which was bred through the cooperative efforts of the science and engineering communities and which has produced a previously unsurpassed quality of life, is often faulted for degrading that very quality of life. Yet it is only through the further application of technology that the ills besetting an industrialized society can be alleviated. Technology has so shrunk the world that the concerns of one nation may come to assume global proportions. And virtually all societal problems today require technology and engineering for their amelioration.

The great advantages that accrued to this country during the golden age, measured in technological progress, balance of payments, or improved way of life, must not be lost. Our scientific and technical lead must be maintained, and our engineers must continue to develop new systems concepts in which the social and environmental constraints are recognized as important elements. If we lose our edge in creativity and innovation, the leadership that we have enjoyed will surely pass into other hands.

These are difficult and complex issues, and they are fully recognized as such by the National Academy of Engineering. Members of the NAE, engaged principally in the technical programs of the Assembly of Engineering, the Academy's operating arm within the National Research Council, are focusing their broad engineering talents on many major and diverse problems, such as the world food shortage, our energy problems, environmental issues, application of space technology to national needs, and improvements in aeronautics, transportation, communications, and other social systems. There is no dearth of problems demanding solutions, and the challenge to our creativity and ingenuity is at least as great as it was during the golden age.

One of the most complex issues facing us today is the role of invention, innovation, and transfer of science and technology in new industrial ventures. Many university programs have been reoriented too far away from these roles of science and technology.

Brilliant young scientists and engineers working in a favorable environment provided great advances in air transportation, including aircraft, propulsion, and air traffic control systems; in electronic digital computation; and in communications and information processing. These products of high technology came from creativity and innovation in a climate that allowed new venture capital to support transfer of new technologies to the industrial world. Thus emerged many new technology-intensive industries that made significant contributions to the nation's progress.

The dampening influences that marked the end of the golden age have brought into sharp focus new and important challenges that must be faced now and in the future. The concerns of society must continue to be recognized as valid constraints; but in recognizing them we must guard against altering the conditions that nurtured the creativity and innovation that was so important to our progress in the past. Today we see the results of these constraining factors in the changing character of some university programs and engineering faculties, in the loss of graduate fellowship support, and in a decline in the interchange between industry and the engineering schools. Beyond this, we also feel the constricting influence of some governmental regulatory actions that impede the flow of new ideas through channels of technology transfer into the economic life of this country. If these key issues are not resolved promptly, many of our lesser concerns may well become academic.

In summary then, this country has recently emerged from a golden age during which science, technology, and engineering experienced exponential growth and produced a flowering of new concepts and majestic systems. A great deal of the motivation for this progress came from deep national fears of certain capability gaps. Most of these fears have now dissipated, and the country is facing new issues closely aligned with present-day problems on earth.

As we look to the future, it is incumbent on the Academy and its members to identify emerging areas of concern; to exercise leadership by defining the relevant issues; and to take appropriate action toward their resolution for the benefit of society.

Engineering prospects are alive and well. We are faced with many new problems that can excite the young minds of our country. But as we lay on each new constraint, we must ensure that we are not stifling the driving factors that have, in large measure, been instrumental in moving this country to the prominent position it enjoys as it approaches the two-hundredth anniversary of its founding.

COURTLAND D. PERKINS

3

Study Projects

NUCLEAR AND ALTERNATIVE ENERGY SYSTEMS

The NRC has been asked by the Energy Research and Development Administration (ERDA) to undertake an 18-month study of the nation's energy future, between 1980 and 2010. The study will consider a broad spectrum of possible sources of energy, recognizing the importance of an energy supply adequate to assure the well-being of society, but keeping in mind also the socioeconomic, environmental, resource, and human costs associated with energy production and consumption. In particular, the study will examine the range of issues surrounding the use of nuclear power in the context of both the probable needs for and the availability of alternative energy sources.

The issues are complex. Energy policy cannot be considered as isolated from domestic societal or foreign policy goals. Further, many energy issues have major uncertainties associated with them. For example,

- The U.S. resource base, primarily for offshore oil, natural gas, and fissile fuels, is highly uncertain.

- The mix of energy supply systems that will be required in the future depends upon an uncertain future rate of growth of both total energy requirements and electricity use.
- The rate and effectiveness of conservation efforts are not fully known and depend both on advances in technology and on changes in institutional arrangements.
- The time required to make advanced technologies available, including the breeder reactor, coal-conversion options, and solar, geothermal, and fusion power, is dependent upon the level and focus of R&D expenditures and the time and effort needed to overcome technological, economic, and environmental uncertainties.

Thus, while the study will focus on the future role of nuclear power, a valid analysis can be made only in the context of a critical examination of total energy needs, alternative energy technologies, and the full spectrum of socioeconomic, environmental and human forces that determine energy supply and demand. With diminishing domestic supplies of petroleum and natural gas, all possible alternative energy supply options must be considered. An assessment of these alternatives must consider a multitude of issues, including the resource use associated with various systems, the need to assure adequate safety and environmental protection, the research and development required to develop new technologies, and the investment required to commercialize newly developed technologies.

Another important issue concerns the use of electricity, which in recent years has been increasing even more rapidly than overall energy consumption. Should this trend continue, new electricity demand would most likely have to be met in the near future by expansion of coal or nuclear generating facilities. Both of these resources have great potential, but both also have serious problems that must be addressed, including rapidly rising costs of implementation and concerns over safety and environmental impact. In this connection, the lead times for research and development, for exploration and exploitation, and for constructing power plants and distribution systems are critical. The lead time for putting a new coal-burning or nuclear-powered electric generating plant on line, for example, is now in the range of 6–10 years. The lead times for achieving appreciable market penetration for alternative sources of electric energy, such as solar, geothermal, or fusion power, are undoubtedly much longer.

Many other energy supply issues require analysis and evaluation.

Technologies for the reliable extraction and economic conversion of coal into synthetic oil and gas have not yet been developed to the point where private investment and production can proceed. Solar and geothermal energy technologies are at an early stage of development, and their progress, promise, and problems need careful evaluation. Fusion power has not yet been demonstrated to be scientifically feasible. One of the most fundamental issues centers on the total impact of nuclear power, in terms of benefits and risks, as well as on a detailed analysis of the nuclear options. This includes examining the various converter and breeder types of reactor systems, and the thorium cycle, as well as subsets of the basic nuclear issues—fuel supply and enrichment, recycling, safety, reliability, wastes, safeguards, health and environmental impacts, and so on.

The demand for energy in the years ahead is dependent on myriad variables, including energy costs, economic growth, population growth, social values, and public policy. No definitive projection of demand can be made; rather, it is possible only to project the ranges in demand determined by various assumptions. Projections of electricity demand are even more difficult. The problem, simply stated, is to prepare to meet an uncertain future demand for energy with a limited number of existing options that may in time be broadened. The effect of conservation on energy demand is also difficult to predict. While there is a growing consensus in favor of conservation programs that may be carried out without adverse effects on employment and standard of living, there is much less consensus on how extensive a cutback in the growth of energy consumption is socially desirable or economically possible in the near future.

With the uncertainties in energy demand, in technological options, and in public acceptability, it would be a specious exercise to prescribe a single array of different energy sources as a guide to the nation's energy planners. Rather, the study will concentrate on assembling sets of alternative energy supply options that can satisfy a range of energy demands. Within the context of any level of demand, it will then be possible to address the role of nuclear power or the implications of its unavailability. With this approach, many issues posed by nuclear power can be analyzed in a setting that also incorporates economic, environmental, and technological judgments on existing and potential alternative energy sources. Similarly, judgments on alternative energy supply options can be made over a range of potential energy demands.

To shape the study, an NRC Committee on Nuclear and Alternative

Energy Systems has been established. Reporting to the committee are several study panels, each focusing on a key element of the energy picture. One panel will examine the potential ranges of energy demand to the year 2010, explicitly analyzing the uncertainties and the forces that shape demand, including energy cost and efficiency of use. Another panel will look at the state of existing and potential energy supply systems and the likelihood of their technical development and implementation in various time frames, while a third panel will assess the comparative risks and impacts associated with each energy option or total system. A synthesis panel will examine issues that cut across the boundaries of the other three panels and will ensure that there are a minimal number of gaps in the overall coverage of the study issues. Each panel will be assisted by a number of specialized resource groups, which will assess particular technologies (e.g., nuclear, solar, coal) or examine specific issues (e.g., efficiency of energy use in buildings, price, elasticity of demand). Information generated by the resource groups will include products of other studies, including collateral studies within the NRC and papers that may be written by individuals connected with or commissioned by the study. Overall, more than a hundred persons will be involved in the study.

In order to evaluate the various policy options, an appraisal will first be made of the present and projected states of the respective energy supply systems and then a series of possible energy-demand scenarios will be developed. These scenarios, or projections of energy demand, will include breakdowns of energy use into the various end-use sectors and of supply into the assumed mixes of supply technologies in the system. Included will be some scenarios that are dominated by social considerations, leading, for example, to restrictions on the development of particular supply systems, such as nuclear. Emphasis will be placed on scenarios that illustrate the impact of variables with major uncertainties that can influence future policy options, such as the quantity of domestic oil and natural gas reserves or the rate of development of nuclear power.

In making the comparisons among the reference energy scenarios and in considering strategies for the development and refinement of nuclear and other supply options, the study will attempt to identify

- The trade-offs (benefits/costs) in the policy choices that society must make

- The uncertainties that come about, in evaluating these trade-offs, from the inclusion in the analyses of factors whose quantitative values are poorly known
- The areas where the uncertainties are both critical to policy choice and amenable to resolution by research
- The sensitivity of future policy choices to current R&D strategies and priorities

The end result will be a report that describes in a coherent fashion the consequences of a series of possible energy policy options, together with an assessment of the potential impact of present ERDA R&D programs on future energy policy choices.

In keeping with the recently established Academy policy that encourages public access, a set of public meetings has been held to allow input from the general public both on the issues that this study should address and on the study plan.

Committee on Nuclear and Alternative Energy Systems, Assembly of Engineering. Committee Co-Chairmen, Harvey Brooks of Harvard University and Edward L. Ginzton of Varian Associates; Study Director, Jack M. Hollander.

METROPOLITAN COMMUNICATIONS FOR THE FUTURE

Effective use of communications technology in a metropolitan setting is a distributed national goal, which is described in Harvey Brooks' essay elsewhere in this report (p. 133) as "largely local in nature, in the approach to . . . solutions, and in the consequences of these solutions." And as with any distributed goal, difficult questions bubble up: What are realiz- 33
able roles for communications technology? What purposes and needs might it meet, immediate and long term? How can maximal benefits be extracted from existing and evolving communications technologies and systems?

These, in their simplest form, are some of the questions now being addressed in an NRC study of future metropolitan communications, funded by a consortium of federal agencies. The intended product is information that can be used by federal policymakers, regulators, operating agencies, and metropolitan governments to guide in an evolutionary way the growth of multipurpose metropolitan communications.

The need for the study and the implicit difficulties it faces were set out indirectly in a 1974 NRC report, *Toward an Understanding of Metropolitan America,** which noted that twentieth century metropolitan growth had a pattern of *aggregation* into a relatively few urban centers, followed by *dispersal* outward into suburbs.

The report also pointed out that technologies such as communication and transportation that provide easier access to the city and its surroundings themselves tended to change the character of metropolitan life:

> As access within the metropolitan community improves, increasing numbers are drawn from the entire region into the orbit of its activities. Meanwhile, the number of those engaged in intermetropolitan transactions also rises. As scale increases, patterns of transaction become more complex, localities merge, boundaries become blurred, and a multicentered, multiassociational form of urban aggregate takes shape.
>
> What is involved is a series of deconcentrating and often mutually reinforcing tendencies in metropolitan areas. Demand for public services rises, stimulating the proliferation of local governments, which, in turn, leads to an acceleration of deconcentrating movements. . . . Eventually there is a relative decline of radial movements and a complex web of crisscross movement becomes commonplace throughout the metropolitan area. A change in one area reverberates rapidly throughout the whole because of the new systemic integrity of its parts.†

Thus, the Study on Metropolitan Communications for the Future confronts a metropolitan pattern formed by aggregation and dispersal, tangled by social, political, and economic complexities, in which three out of four Americans now live. The Study approaches the metropolitan conundrum with an awareness of the potentials and range of telecommunications technology. However, as is emphasized in the Study's work statement, "This is not to be merely a narrow study of systems and hardware. It is to be an engineering study in the broadest sense, that is, a study

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* National Research Council. 1974. Toward an understanding of metropolitan America. San Francisco: Canfield Press.

† *Ibid.*, pp. 12–13.

of how technology might be utilized to accomplish recognized social goals."

The range of communications technology now on hand is truly extraordinary. It makes possible high-speed, high-volume transmission of information—data, voice, and pictures. Computer-aided switching systems provide fast access to memory stores of many types and also permit precise control of the routing of electronic data through telephones, open and closed circuit video systems, and domestic and international satellites. At terminals, there are display devices of various sorts: printers, recorders, video playbacks, facsimile machines, and so on. These existing systems are fed by still developing technologies such as large-scale integration, new metallic oxide silicon devices, more reliable, high-capacity satellite and undersea systems, new data-compression circuitry, and microwave and guided-wave optical systems.

The issue in metropolitan communications is obviously not more technology. We know that some will work and some will not. Some will be worth the costs and some will not. Some will be suited to certain needs, but not others. Some should be redesigned for wider use—for others it is impossible to foresee all of the possible uses.

The ideal is one or at least a few common communications systems for many different metropolitan needs. The actual pattern has been separate systems for separate uses. Police, fire, and health departments in a community may use communications systems relying on similar modes of transmission, switching, memory storage, and information processing. But each system is funded and operated separately. A tele-medicine system of a state department of health may seem superficially different from a computer-assisted instruction system installed by a board of education. But, again, the two may use similar technologies of switching, transmission, and memory storage. Can such technologically similar systems be planned to accommodate the different uses? Can they be planned in a way that easily admits new users and new needs? What roles can and should federal agencies play in this process?

The proposal for this study cited "pressing metropolitan needs." One is the familiar example of substituting telecommunications for transportation: electronic travel rather than physical. While the idea has reached the level of cant, there is little apparent evidence that communications as an alternative is a common factor in transportation planning. The more usual pattern in metropolitan growth has been separate planning of communication and transportation. This thesis is enunciated by Edward M. Dickson and Raymond Bowers,* who believe that, relative to transportation, telecommunications technology is underexploited.

"In many respects," they comment, "the state of telecommunications technology today resembles transportation technology in the 1920's when the potentials of the automobile and the airplane were just being perceived and exploited." There are, of course, crucial differences between transportation and communications; in some cases they may substitute for each other and in other cases not. Careful analysis, including analysis of the human factors involved, is necessary to avoid counterproductive actions. Introduction and expansion of new communications networks—the video phone, for example—could sap efforts to expand public transit. The study will, in part, examine some of the issues of transportation vis-à-vis communications.

There are other metropolitan needs that may be looked at. How do citizens talk to their local governments? How do they find the right information, office, and official? How do public officials get fast responses to questions about the workability of new programs and policies? How does a driver seeing a fire quickly report it? How does he report his location and that of the fire? How do we make better use of a limited and geographically concentrated corps of physicians? Can communications technology provide rapid, accurate, and inexpensive detection of air and water pollutants?

And what are the possibilities for electronic mail? What are ways to apply the "narrowcasting" capabilities of cable television? What effects will new technologies such as the video phone have on the standard telephone and cable television? Do satellites have a role in metropolitan communications?

Quite obviously, whatever issues arise during the study will have been tested against several realities. For example, a metropolis is normally not a political entity; it is a geographical and statistical one. A metropolitan area is a patchwork of county, city, and town governments, each structured somewhat differently and each with its own local imperatives. Such split jurisdictions make collective action difficult, particularly if an idea is

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* E. M. Dickson and R. Bowers. 1973. The video telephone. New York: Praeger, pp. 125–127.

novel. Capital costs may be high, federal aid too little or unavailable, and the arguments of life-cycle costs not congruent with annual budget making. Various citizen groups may raise legitimate issues of privacy and confidentiality.

Present plans are for the study to cover current technology and its improved application to present and potential uses over the next 5 years (1976–1980). A follow-on phase of the study would cover new technologies (examples: fiber optics, computer systems, satellite systems, digital communications) and their integrated application after 1980.

Metropolitan Communications for the Future, Committee on Telecommunications, Assembly of Engineering. Study Chairman, Henri G. Busignies of the ITT Corporation; Staff Officer, R. V. Mrozinski.

ADVANCED ENERGY STORAGE SYSTEMS

At the request of the Energy Research and Development Administration (ERDA), an *ad hoc* committee of the Energy Engineering Board of the Assembly of Engineering is conducting a 1-year study of R&D for advanced energy storage systems. Not to be confused with fuel storage, the energy storage problem is primarily associated with techniques for effectively storing electricity.

Unlike fuels such as coal or petroleum products, which can be stored in piles, bins, tanks, or pressurized containers after being extracted or refined, electrical energy is produced and consumed instantaneously. Consequently, the electric utility systems must have the generating capacity to meet the maximum combined electrical demand, regardless of the infrequency with which that demand is imposed.

The demand for electricity is a function of our work habits and life styles; these have developed in patterns that result in highly fluctuating electrical loads. For example, industrial activity is at a peak during the day shift; on hot summer afternoons the industrial load is augmented by residential and commercial air-conditioning loads, producing the highest electrical demands of the year. By contrast, demand levels are markedly lower in the early morning hours and on weekends.

Since the utilities must have enough generating capacity to meet the highest peak loads, it follows that much of the equipment either stands idle or is lightly loaded for part of the time. Although fuel costs for generating electricity occur only when the units are in use, the capitalization costs run continuously, whether the equipment is in use or not. As a consequence, the price of electricity has to be high enough to pay off the idle equipment.

The utilities try to minimize overall costs by deploying a mix of generating equipment. Large, fuel-efficient "base-load" generators are installed to meet the electrical demand levels that occur most of the time. Typically, this capacity might supply about 60 percent of the peak load and be fully loaded about two-thirds of the time. Smaller, more flexible "intermediate-load" units furnish an additional 20 percent or so of the peak demand load and are run at full capacity perhaps 30 percent of the time. The top 20 percent of the peak electrical demand is generally encountered no more than 30 percent of the time; special "peak-load" units are employed to handle this load segment. Since these peak-load generating units stand idle most of the time, a premium is placed on low capital costs rather than on high efficiency. Where possible, older fossil-fuel units are used for peak loads, but low-cost modified aircraft gas-turbine-driven units are increasingly being installed for these purposes. Not only is the fuel efficiency low for such units, but they generally require petroleum products (natural gas or oil) as fuels.

The electrical capacity needed by the nation is expected to grow markedly in the decades ahead. Unless there are great shifts in consumption patterns, perhaps induced by changes in rate structures, the present disparities between peak and average demands will continue or even increase. Most of the added base-load capacity will be from coal-fired or nuclear-powered generators, both of which are relatively efficient and use nonscarce fuels. These units will not be fully loaded around the clock, however, so they will contain a reservoir of unused energy capability. If satisfactory techniques can be developed to store electricity, these units could be run continuously at full power ratings, and the energy in excess of instantaneous demands could be stored to meet part or all of the intermittent peak loads, thereby reducing or eliminating the need for the expansion of petroleum-fueled peak-load units.

Such storage might be done at the generating site, at distribution substations (which would also reduce the capital investment needed for peak-load transmission capacity), or at the load use center, i.e., at the factory or the home.

The storage might or might not be in the form of electricity. The principal, though limited, current storage method is a form of electromechanical storage. Termed "pumped storage," off-peak power runs electrically driven water pumps to raise water to a higher storage reservoir. At peak-load conditions, this water is used to drive hydroelectric generators to meet the demand. Although there are net energy losses due to system inefficiencies, the lower capital costs and the higher utilization of the base-load equipment make the system economically advantageous to the consumer.

Other forms of electromechanical storage have been proposed and need further R&D investigation. These include underground hydroelectric generators with surface storage of the water, storage of compressed air to drive turbogenerators, and storage of kinetic energy in large flywheels.

Electrothermal storage may also become an important system, particularly for the user. In electrically heated homes, for example, the electricity is currently consumed as needed. If suitable thermal storage systems can be developed, it would be possible to consume electricity during the late night, off-peak periods to generate heat that could be stored and used throughout the day as needed. Similar long-term possibilities exist for air-conditioning.

Electrochemical storage also holds promise. Off-peak electricity might be used to electrolyze water into hydrogen and oxygen, which could be stored and then converted back into electricity in fuel cells during the peak-load periods. This technology might be the precursor of a "hydrogen economy," in which the hydrogen could be used directly as fuel to replace petroleum products in many uses.

Direct storage of electricity is also feasible. Advanced storage batteries are the subject of considerable R&D. Similar in concept to automobile storage batteries, utility batteries must have lifetimes of about 20 years and must be capable of 5,000 or more deep discharge cycles to be satisfactory. Farther into the future is the possibility of direct electricity storage in superconducting magnets. Supercooled by liquid helium, such storage devices might have very large energy capacities.

In addition to creating economic savings in an expanding electric utility industry, the development of energy storage systems would shift a greater share of electricity production to coal-fired or nuclear-powered base-load generating equipment, thereby substituting these relatively abundant fuels for the scarce oil and gas now consumed in peak-load equipment. Additionally, the use of storage systems would level the load on the large base-load generating equipment and reduce power cycling, which often causes control problems and, in the case of nuclear reactors, can reduce the lifetime of fuel elements. Furthermore, in the longer term, energy storage systems will be essential to the viability of intermittent solar power sources and of the expensive fusion power systems.

A primary objective of the NRC study of energy storage systems will be the development of guidance criteria that ERDA will use in selecting the content and priority of its sponsored R&D activities. The principal beneficiaries of useful developments will be private electricity consumers, who will benefit if the advances are implemented by the largely private and generally nonfederal utilities and their suppliers. One of the basic program considerations, therefore, will be the determination of the appropriate conditions for ERDA to sponsor and fund R&D that must be applied by the private sector to be useful. A corollary consideration is how ERDA should conduct its R&D in order to maximize the probability that the results will be useful to and utilized by the private sector. Additionally, criteria for identifying the critical technical parameters requiring R&D attention and for estimating the comparative benefits and costs of competitive concepts must receive consideration.

Appropriate guidance criteria for such considerations will be neither simple nor universal. The criteria may be expected to vary, depending upon the state of the technology under investigation; the preliminary, exploratory research on new concepts must be viewed quite differently from full-blown systems demonstration projects. In addition, the characteristics of the anticipated user sector will influence the decision criteria. At one extreme, the utilities represent a highly aggregated industry with well-developed technical and economic requirements. At the other extreme, the potential residential market for energy storage devices is highly disaggregated and relatively unsophisticated in evaluating technical and economic trade-offs. The technical nature of the energy storage system will also influence R&D decisions to some degree. Technologies that are unique to a specific application must be viewed differently from those that have multiple potential uses. For example, although technical requirements differ in detail, R&D on utility storage batteries must take into account R&D on storage batteries for electric automobiles to be most effective.

In addition to developing criteria for R&D project evaluation, the NRC study will survey the current state of the art in energy storage and will recommend broad program priorities for R&D, including the portion deemed suitable for government sponsorship.

Committee on Advanced Energy Storage Systems, Assembly of Engineering. Chairman, W. Kenneth Davis, Bechtel Power Corporation; Staff Officer, DeMarquis D. Wyatt.

MINORITIES IN ENGINEERING

"Engineering is the largest professional occupation for men in the U.S., employing more than a million persons," according to a 1974 Sloan Foundation report on *Minorities in Engineering.*[*] That report made clear how limited is the participation of several American minorities—blacks, Chicanos (Mexican-Americans), Puerto Ricans, and American Indians—in the engineering profession. These groups comprise 15 percent of the U.S. population but less than 3 percent of all engineers and less than 5 percent of all engineering students.

Beyond the numbers, the missing minorities in engineering signify the *de facto* exclusion of an important part of the American people from the technological mainstream of society. The costs are heavy. Engineering skills are indispensable to many jobs, often vital to improved pay and advancement, and increasingly necessary to achievement of executive rank.

In short, engineering can be an effective entry point into a technological society. Why have minorities not used it? As the Sloan Foundation report and other studies have shown, there are a multiplicity of barriers, some specific to engineering and others due to the general problems of

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[*] *Minorities in Engineering, A Blueprint for Action.* A Report of the Planning Commission for Expanding Minority Opportunities in Engineering. The Alfred P. Sloan Foundation, New York, 1974.

minority participation in the professions: poor education in elementary school and high school; economic pressures forcing early dropout; failure by teachers to recognize and encourage promising minority students; language difficulties for many Spanish-speaking and American Indian students; little advice to the minority student on where and how to apply to a school, and where to find support; and ignorance of the engineering profession and the particular opportunities it offers in work satisfaction, reward, and advancement.

In 1973, the National Academy of Engineering organized a Symposium on Increasing Minority Participation in Engineering. Within a year after the symposium, the NAE encouraged the creation of the National Advisory Council on Minorities in Engineering. This group—composed of members from the highest level of industry, government, and education—in turn seeded, through the provision of $300,000 by its industrial members, the Committee on Minorities in Engineering, initially within the NAE and later within the Assembly of Engineering of the National Research Council.

The Committee quickly learned that while the lack of minorities in engineering is a national problem, it is not amenable to a national program. Identifying and encouraging the promising black student in Detroit is a different task from helping the Puerto Rican in New York still trying to cope with English. Nor does the Navajo student in Arizona, with his cultural orientation and tribal values, respond in the same way to advice given the Chicano in Los Angeles or San Antonio.

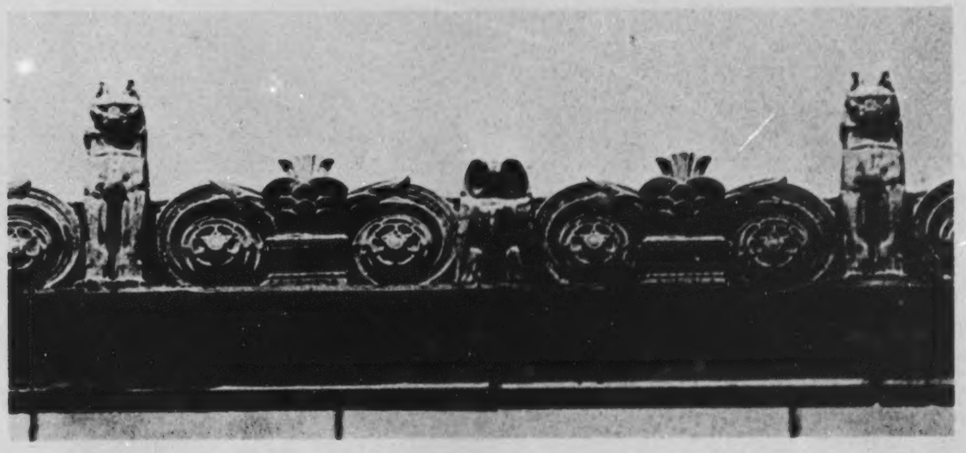
There are now several organizations working regionally and nationally to deal with the particular problems of particular minorities. The Committee on Minorities in Engineering has tried to help them by providing needed data or pointing to likely sources of data; by helping to set enrollment goals; by assisting in gaining resources; and by helping groups working on the problem to know what others are doing—what things have worked, and what have not.

The Committee has been a goad and guide to these organizations, many anxious to "do something," but in danger of suffering the fate of Stephen Leacock's horseman by riding off in all directions at once. The Committee has provided "role models" for career days, has been a source of information, and has acted as an objective and knowledgeable assessor of progress and results.

Aside from this "central office" role, the Committee has grappled with specific problems. For instance, of the minority students that do go on to college, a disproportionate number go to 2-year community colleges. And, lured by high starting pay, many stop after 2 years, although they may have the ability to do advanced work in engineering and similar fields. But, in a credential-conscious society, lack of a degree prevents significant advancement later. The Committee has looked at the problem and has evaluated transfer barriers, suggesting ways in which community colleges can identify and encourage the gifted student.

In 1975, the Committee published a study, *Building Effective Minority Engineering Programs,* which includes statistical data on engineering enrollment among blacks, Spanish-speaking persons, and American Indians. With the support of the Sloan Foundation, the Committee conceived the National Fund for Minority Engineering Students, an independent, nonprofit organization that provides scholarship aid from many sources. In June 1975, the Committee conducted a workshop for minority program managers at engineering schools and for guidance counselors and administrators in secondary schools at which they exchanged ideas, approaches, and experiences.

Committee on Minorities in Engineering, Assembly of Engineering. Chairman, Arthur G. Hansen of Purdue University; Executive Director, Melvin H. Thompson.



JAMES D. EBERT
Chairman, Assembly of Life Sciences

Assembly of Life Sciences

4

The Assembly of Life Sciences: An Operational Definition

The Assembly of Life Sciences (ALS) is an extraordinary congeries of boards, committees, institutes, and short- and long-range programs whose origins—some recent and some in the distant past—include the Division of Medical Sciences and portions of the Divisions of Biology and Agriculture, Engineering, and Chemistry and Chemical Technology.

A view of one's domain usually has two components: pointing with pride and viewing with alarm. In the Assembly of Life Sciences, we do not point with pride at our size, which is enormous by any standard, whether judged by our share of the National Research Council's seven thousand volunteers or by our annual budget. Our annual budget, approximately $15 million in 1975, is especially horrendous to an old-fashioned embryologist like myself, some of whose recent experiments each cost less than $100. We do point with pride at the dedication, insight, and perception displayed by our human resources. I have been privileged to work with the Chairmen of the Divisions of Medical Sciences and Biological Sciences, Paul Marks of Columbia University and Donald Kennedy of Stanford University, respectively, with a critical and effective Executive Committee composed largely of members of the National Academy of Sciences and the Institute of Medicine, and with an able staff under the leadership of Thomas J. Kennedy, Jr.

How *does* one describe such a far-flung domain? It seems to me that perhaps the most effective way of depicting the Assembly of Life Sciences is to guide you through a single meeting in the life of a member of our Executive Committee, whether that member is—as the members are—a geneticist, a neurobiologist, an internist, a botanist, or an ecologist.

This "typical" meeting opened with a consideration of the role of the Committee on Health Care Resources in the Veterans' Administration (see page 52). The Veterans' Administration operates what is probably the world's largest health care delivery system, with a Fiscal Year 1976 budget of over $4 billion. If we are to have a national health care policy (and we are said to be seeking one), an analysis of the manner in which the Veterans' Administration conducts its business provides an interesting starting point, to say the least. This Committee is attempting to understand the several roles being played by the Veterans' Administration in the health care enterprise, to determine the cost effectiveness with which the Department of Medicine and Surgery of the Veterans' Administration is carrying out its mission, and to evaluate the adequacy of the staff and the quality of health care being delivered. The Executive Committee of our Assembly was asked to review the work of the Committee, which is chaired by Saul J. Farber, and to determine whether the proposed budget of $6.5 million would be sufficient to carry out a task of this magnitude. That was the opening assignment for the day.

In conjunction with that discussion, the Executive Committee also briefly reviewed the work of a related committee that was assessing the quality of biomedical research in the Veterans' Administration.

The ALS Executive Committee next turned its attention to the report of the Visiting Committee to the Committee on Prosthetics Research and Development (CPRD). One of the long-standing and significant activities of the Division of Medical Sciences, CPRD brought together physicians and engineers concerned with the problems of the nation's handicapped. As so often happens with long-standing organizations, questions have been raised—questions not of the importance of continuing aid to the handicapped, but of whether the problems have grown so complex that our administrative structures are no longer competent to deal with them.

After that discussion, the Executive Committee took up a request from the Occupational Safety and Health Administration (OSHA) to work closely with it and with the National Cancer Institute in a program designed to look into the serious question of how to educate workers about cancers arising from occupational hazards—e.g., vinyl chloride, benzene, and asbestos.

We then reviewed the Toxicology Information Program, in which the National Library of Medicine, with advice from an ALS committee, provides institutions in the United States—through an organization called TOXLINE—with up-to-date information on the identification of chemicals that may have important toxicologic consequences.

The Committee then turned its attention to the Institutional Differences Study. This study, completed in 1975, suggests what to many of us is a frightening thought: that there are widespread differences in the quality of surgical care throughout the United States. Are our chances for survival and for a happy outcome of a given surgical procedure substantially better in one institution than in another? Is the magnitude of the difference larger than any of us have suspected?

We turned next to a consideration of the nature of the Assembly of Life Sciences itself. The Assembly of Life Sciences has no "membership" in the usual sense of "a gathering of persons for deliberation and legislation," apart from the Executive Committee. There is no larger "voting body." We have developed a network of corresponding societies, and we publish a newsletter, *Lifelines*, available on request. We were concerned, however, that the Executive Committee of our Assembly may not fully represent the nation's younger scientists—that there is insufficient involvement of younger investigators and teachers in the activities of the National Research Council.

We see what we are conditioned to see. In the foreword to *Between Pacific Tides* John Steinbeck put it most eloquently: "There is in our community an elderly painter of seascapes who knows the sea so well that he no longer goes to look at it when he paints. He dislikes intensely the work of a young painter who sets his easel on the beach and paints things his elder does not remember having seen." The Executive Committee is attempting to develop a panel of consultants—a network of dedicated and highly competent advisors among the younger members of the scientific community.

We then turned to a consideration of a number of proposals from the

Food and Nutrition Board on the role of nutrition in dental health, nutrition and immunity, and other subjects.

The Executive Committee next looked at a proposal from the Bureau of Radiological Health. Questions occasionally come to us that nonmedical persons like myself think must have been answered at least a decade ago. In the discussion it emerged that some medical practitioners have not heeded earlier warnings of the unhappy consequences of radiation and are still using radiation techniques for the treatment of relatively benign conditions. The National Research Council has been called upon, through its Assembly of Life Sciences, to reexamine the question. I think the scientific answers will not be any different from those of a decade ago. But perhaps, if the question is restated and the answers are directed through new channels, another audience will be reached and the problem may be alleviated.

We then took ourselves into a discussion of problems of pesticides and toxicology, a large and nebulous field, one in which relatively few practitioners define themselves as "toxicologists" in the strict sense. We find it extraordinarily difficult to bring to bear on such problems the expertise that they so often require. For example, we have constituted a major committee (a visiting committee, in a sense) to examine the National Center for Toxicological Research.

We then reviewed a subject that, in my view, was one of our most exciting during 1975—the study of recombinant DNA molecules, a program organized under the direction of Paul Berg and David Baltimore to deal with the potential biohazards arising from the new-found capacity to chemically couple DNAs from different species. The possibilities exist that one may insert into the genome of a common bacterium like *E. coli*, which all of us carry with us at all times, the DNA of a foreign type—as exotic as the DNA of the clawed toad *Xenopus laevis* or, more frightening, the DNA of a tumor virus. These techniques, which introduce new and strange forms of DNA into biology, place us in an area with many unknowns. The evaluation of biohazards is extremely difficult. The participants at the conference agreed that most of the work on constructing recombinant molecules should proceed, provided appropriate safeguards are employed, but that certain "high risk" experiments ought not to be done until we know that they are less hazardous than we now suspect or until better containment facilities are available. (The Asilomar guidelines have been thoroughly discussed and revised since the conference. Nevertheless, this extraordinary gathering illustrated that the scientific community is increasingly prepared to police itself and to interact with other segments of society in examining hazards of biological and biomedical techniques.)

We then moved to a question raised by one of our corresponding societies: the threat to research in many biological fields, owing to the intensive harvesting, by both American and foreign fishermen, of common marine animals. The squid, used in neurobiological research for several decades, is rapidly disappearing from the shores of New England, and we still do not understand how to cultivate it in captivity. Yet squid are being harvested for food in enormous numbers by factory ships just as fish are. On the West Coast, the same thing is happening to the sea urchin. If we are to preserve these resources, we must take early action.

Similar problems are being met with many vertebrates of research importance, including not only a number of species of wild primates but even so mundane an animal as the common grass frog. And the availability of wild-caught organisms as experimental material is only part of the problem. We need to broaden and to improve our facilities for maintaining germ-plasm resources and genetic stocks, stocks of microorganisms, of animal cells in culture, of cultivated and wild plants, and of a variety of laboratory mammals. A significant part of the future activity of the Division of Biological Sciences will be devoted to an examination of these resource problems.

This recital is not simply a form of "show and tell," nor is it designed to demonstrate the remarkable capacity, versatility, and wisdom of the Executive Committee. It is designed to point up what I consider the awesome responsibilities of this Executive Committee—indeed, of all the Assemblies and Commissions. In that one meeting, this group had to consider as part of its responsibility the wise expenditure of some ten million dollars. It had to consider the development of programs that in the long run will have a profound impact on the health and safety of all of us. It considered programs that will affect the breadth and depth and health of the scientific enterprise—such as the symposium on DNA recombinants—and, finally, the Committee's deliberations have had a profound effect on substantial segments of American industry, especially those dealing with foods and with drugs.

Against this background, let me point up four problems that my colleagues and I see looming ahead; perhaps, to some degree, these represent problems faced by all of us within the National Research Council.

First, we need to be more active in initiating our own proposals, while continuing to be responsive to the initiatives of others. We have been less active, I think, than we should be in our own Assembly, in part because the characteristics of problems with which we must deal have not yet been clearly delineated. To that end, all members of the scientific community are potential contributors, and we welcome suggestions. It seems to us that the Assembly of Life Sciences performs best, most effectively, when it deals with problems in which the key issues require debate and balanced consideration by a selected group of scientists pooling their insights and experiences in arriving at judgments. The common mechanisms are committees, workshops, and symposia. Ideally, the issues at stake are best handled when they are essentially scientific. Our own Assembly seems to me to have functioned uniquely well when the history, the strength, and the reputation of the National Research Council were essential in enlisting the participation of persons whose knowledge was required. In short, we perform best when the committee, in the broad and best sense of that term, is the key element in the work.

Second, a number of forces whose impact is perhaps inescapable today are conspiring to make far more difficult the achievement of standards of excellence that all of us hope will epitomize the activities of the National Research Council. The demands on the time and energies of the nation's best, or at least its best-known, scientists are brutal and, to the extent that these scientists are overworked, their productivity is bound to suffer. To this end, we must limit our programs to problems of significance, lest rare talents be diverted to second-order issues; the reduction in demand on scientists of the first rank should enable them to function more effectively. We must make it a deliberate policy to seek new and untried talent, and we enlist aid in that effort.

Third, I come to one of our most difficult problems: We are beginning
50 to accrue a substantial number of large-scale projects, like the study of health care delivery in the Veterans' Administration, that are by their nature *staff*-intensive, rather than *committee*-intensive. I am not sure that we are going to be able to handle these as well as we would like to within the traditional *modus operandi* of the Academies. These projects demand short response times, and thus it is difficult to build up a highly qualified

staff of the size that one needs to deal with a six- to seven-million-dollar project. In the short experience, now more than 2 years, of our Executive Committee, we sense that our effectiveness is most seriously challenged when the scientific issues are difficult to separate from the political issues, when there is need for a prompt response, and when the response needed is a direct exchange of opinion, that is, advice given face-to-face with an agency or a congressman. When the project involves a large amount of data-handling or information-gathering, we tend to have limitations.

Finally, the decision still hangs in the balance on the propriety and the wisdom of maintaining within these halls specific functions and responsibilities over long periods—I mean several decades—as is true of some of our activities. One of the earliest decisions of our Executive Committee was to constitute visiting committees to review long-standing operations, like the Committee on Prosthetics Research and Development, the Advisory Center on Toxicology, and the Drug Research Board. This year, visiting committees will be constituted to look at the Food and Nutrition Board and the Institute of Laboratory Animal Resources. It is already clear that the visiting committees have made, or will soon make, recommendations for major changes, some of which have already been accepted and are being implemented. In the course of these examinations, the extent to which originally desirable and well-understood functions can become transformed has been striking and has emphasized the importance of thorough periodic review and reevaluation.

All in all, I think the Assembly, still young, is growing in competence, modulated by aspirations to high quality and struggling to attain and sustain standards of excellence.

JAMES D. EBERT

5

Study Projects

HEALTH CARE RESOURCES IN THE VETERANS' ADMINISTRATION

Public Law 93–82, which was signed by the President on August 2, 1973, includes a provision that requires the Administrator of Veterans Affairs to negotiate an agreement with the National Academy of Sciences under which

> such Academy (utilizing its full resources and expertise) will conduct an extensive review and appraisal of personnel and other resource requirements in Veterans Administration hospitals, clinics, and other medical facilities to determine a basis for the optimum numbers and categories of such personnel and other resources needed to ensure the provision to eligible veterans of high quality care in all hospital, medical, domiciliary, and nursing home facilities.

The Academy entered into such an agreement in November 1973, and the contract requires the Academy to deliver its report to the Congress in November 1976.

The study is budgeted at $6 million, which makes it one of the largest ever undertaken under Academy auspices. It is policy oriented and is intended to provide a basis for public policy decisions on the changing role of the VA hospital system and the resources required to carry out this role. The VA health care system was developed at a time when the federal government had only marginal responsibilities for health care for the general population. In the last 10 years, the federal role in health care has grown enormously, and it is likely to continue to grow rapidly. The problem of modifying the role of the VA medical system in the most appropriate and realistic way, within an expanding federal role in health care, poses a series of complex questions that the study will try to answer.

The VA health care system is a unique enterprise. It now includes 171 hospitals with about 95,000 beds and has a fiscal year 1976 budget of over $4 billion. It discharged about 1 million inpatients and processed approximately 15 million outpatient visits in 1974 in its own facilities and contracted for substantial amounts of additional services in non-VA facilities. Eighty-nine medical schools have affiliation agreements with 109 VA hospitals. About 50 of these affiliations are extensive, involving substantial patient care responsibilities by medical school faculty and clinical training of medical students and residents in VA hospitals. Thousands of health professional students are trained in VA facilities every year. A very substantial fraction of all residents in medicine, surgery, and psychiatry receive at least part of their training in VA hospitals.

There are 29 million veterans in the United States: 14 million are World War II veterans whose median age is over 55, 1 million are World War I veterans, and the balance are younger. Over 40 percent of all males 18 years of age or older are veterans. The provisions of law have gradually been broadened—particularly since World War II, although the process actually started in 1924—to permit the use of VA facilities by veterans who do not have service-connected disabilities but who need medical help and cannot afford to pay for it. At present, the eligibility laws are such that essentially any veteran who needs medical care from the VA can apply for such care and obtain it (on a space-available basis) merely by signing a statement that he cannot afford to pay for it. By law, there is no means test.

Thus, while the VA hospital system was established primarily to provide health care to veterans with service-connected disabilities, 85 percent of the care actually provided is for non-service-connected health problems.

The growth of the VA hospital system, the extensive affiliation relationships, and the fact that some 170,000 people are employed by the system have all given the VA Department of Medicine and Surgery very substantial political support. The department grew up and assumed its present form during a period when the federal role in and responsibilities for health care of the general public were very limited. Before 1960 the federal health role was essentially to provide health care for a relatively small number of federal beneficiaries such as Indians, merchant seamen, and members of the uniformed services; to provide matching grants for construction of community hospitals; and to support biomedical research and training. Since then, and particularly with the passage of Medicare and Medicaid in 1965, federal responsibilities for health care have grown enormously. In 1974, of approximately $105 billion spent on health in the United States, some $40 billion flowed from federal coffers. Thus, it is clear that the VA health care system—a miniature National Health Service operated for the benefit of veterans—must be viewed in the context of the overall federal responsibilities for health care. This is particularly true with regard to the issues of access to health care and of the costs and effectiveness of such care, which are in the forefront of the current public policy debate in the health field.

With some form of national health insurance likely to be enacted into law in the next few years, these questions assume even greater urgency. The Congress, in requesting this study, clearly had these issues very much in mind. As the country forges new health policies affecting the people as a whole, the role of the VA and the resources required to discharge this role effectively can no longer be viewed as a problem unrelated to that of the broader federal role in health. Both the emergent national health insurance and the changing role of the VA's Department of Medicine and Surgery will involve efforts to rationalize and improve the efficiency of resources devoted to health care and to establish controls on the costs and quality of health care provided. Legislation recognizing the potential relationships has already been enacted. For example, legislation authorizing the VA to train health manpower to meet the general requirements of the country—not just of the VA health care system—has been on the books for some time; however, there is no mechanism available to the VA that enables it to allocate its resources for training in a way that would rationally relate the VA's activities to the country's needs. Similarly, authority to share VA resources with those of the community for certain specialized medical services exists, and some sharing arrangements have been worked out with community resources under which the VA provides services to nonveterans and utilizes non-VA facilities in the community for veterans. Furthermore, in 1974 the VA was authorized to accept reimbursement for provision of hemodialysis and kidney transplantation services to nonveterans.

Thus, it is clearly not possible to respond to the congressional charge without addressing the issue of the future role of the VA (after national health insurance is adopted), since the resources required to discharge the VA mission will clearly depend on the *de facto* and *de jure* roles the VA will be called upon to play.

The type of services demanded of the VA systems in the next 10 to 15 years will be shaped by at least three somewhat contradictory factors: national health insurance, which, if enacted, would provide access to community facilities for at least some of the current users of the VA acute medical and surgical services, and hence a reduced demand for such services in VA hospitals; a probable steadily increased demand on the system for geriatric care by the 15 million World War I and World War II veterans; and a probable demand for a wider variety of VA services—particularly ambulatory care—as facilities in non-VA hospitals are overtaxed.

These likely changes and the others—availability to the general population of necessary health services, a strong governmental role in controlling the costs and quality of health care, and continuing concern with the perceived inadequacies of health care such as the maldistribution of resources—will inevitably change the role of the VA's Department of Medicine and Surgery. The policies affected will probably be those concerned with:

Determining the optimum amounts and distribution of staff and other resources for the VA health care system

The management arrangements and procedures governing the system's operations

Eligibility

Relationship of VA facilities and resources to the non-federal facilities and resources of the communities in which VA hospitals are located

The NRC study is designed to provide information that can be used to formulate policies in these areas. The study is inherently a complex and many-faceted one, involving extensive data gathering and field interviews. The study will include the following elements:

1. A series of cross-sectional studies focused on access, utilization, and quality of care in a sample of VA hospitals. Data will be obtained from analysis of patient records, from interviews with patients, and from applicants for care as well as from VA staff.

2. Studies of hospital staffing (including nursing, dentistry, psychiatry, and allied health and support occupations) and the quality of nursing care in acute bed sections of VA hospitals.

3. A survey of a sample of all veterans living in six VA hospital "catchment areas," regional territories often cutting across state lines. The survey will gather data on the use of VA hospitals by a representative population of veterans and on their use of non-VA health care facilities.

4. A survey of VA staff to ascertain their views on a number of key issues.

5. A survey of medical schools affiliated with VA hospitals. Since World War II, most new hospitals built by the VA and others in urban settings have had teaching affiliations with medical schools; this relationship is affected by the degree of dependency between the VA hospitals and the medical schools.

6. Study of VA dental care. This is an intensive review to determine the extent of dental care and the availability of prosthetic services for dental injuries and defects.

7. Study of ambulatory/outpatient care. Recent legislation and directives have increased ambulatory/outpatient care in many VA hospitals; this study will use site visits to obtain data on facilities and patients' experiences.

8. Utilization and cost studies. These involve an analysis of length of stay in VA hospitals, an analysis of manpower costs in VA hospitals, and a longitudinal study of selected VA patients.

9. Study of potential relationships between VA and non-VA hospitals. The potential for sharing certain selected, specialized medical services with community hospitals will be studied.

10. Long-term-care study. This study will include data gathered

from site visits to domiciliaries, nursing-care units and homes, and intermediate-care sections.

11. Evaluation of rehabilitation medicine. Rehabilitation medicine, including spinal cord injury and prosthetic services, will be studied in a selected group of hospitals.

Committee on Health Care Resources in the Veterans Administration, Assembly of Life Sciences. Chairman, Dr. Saul J. Farber of the New York University School of Medicine; Study Director, David Tilson.

MEDICAL FOLLOW-UP: TWIN REGISTRY AND PRENATAL X-RAY

TWIN REGISTRY

The study of twins to unravel the mingled influence of genetics and environment in shaping health and fortune was first suggested about 100 years ago. Francis Galton, Charles Darwin's grandson and a founder of modern statistics, described the potential value of twin study in his book *The History of Twins as a Criterion of the Relative Powers of Nature and Nurture* (1875). Since then, there have been a profusion of twin studies, ranging in size from reports on one twin pair to the registration of a nation's entire twin population.

The underlying idea in twin studies is that since identical twins have identical genes, any differences between twins in health and achievement are due to environmental differences and chance. Fraternal twins share in common only *half* their genes; thus, if their medical histories differ more than those of identical twins, the extra variation can be ascribed to genetic differences.

However, the results of twin studies must be carefully applied and interpreted. For example, the fact that the same cancer shows up in two identical twins at the same time is not proof of a genetic etiology; perhaps they shared a common "item of experience" that caused the cancer. Comparative data on fraternal and identical twins can, according to a

World Health Organization (WHO) report on twin studies,* "do no more than to draw attention to the presumptive importance of genetic factors." Further, twins differ in a number of ways from single births. As the WHO report emphasized, twins

> develop in a uterus primarily adapted to the nourishment of a single fetus. They are usually less mature at birth when they are exposed to increased risk of obstetric complication. If both survive, their development may be impaired by difficulties in lactation. Their upbringing is unusual, as it is shared by a sib of their own age, and they are known to have an increased mortality in childhood.

Thus, twins are a biologically selected group, not necessarily representative of the general population. An additional weakness of many twin studies is that the subjects are often children. They are easier to find than adults, records are usually more detailed, and they—or their parents—are more cooperative and generally more willing to put up with the puzzling demands of a researcher. But many of the "nature and nurture" questions now being asked center on chronic diseases—malignancies, cardiovascular disease, and other degenerative diseases—that do not appear until middle age. Moreover, study of these diseases requires a large population if there are to be enough occurrences of different diseases for analysis by age of occurrence, antecedent events, and so on.

It was the need for such a resource—a large population of adult twins—that led to the organization in the late 1950s of the Twin Registry by the Medical Follow-up Agency of the National Research Council. Today, the Registry has the names and records of 16,000 male twin pairs, all World War II veterans 49 to 59 years old. The Registry has been and is being used to address a wide range of problems, from the genetics of migraine headaches to the varying effects of genetics and experience on earning differences between individuals.

The Twin Registry was established by obtaining the names of white male twins born between 1917 and 1927 from birth records in local vital statistics offices. The names were then searched through the Veterans' Administration Master Index, which contains the records of virtually all World War II veterans. Birth certificates for 54,000 twin pairs were found

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* World Health Organization. 1966. The use of twins in epidemiological studies. Acta Genet. Med. 15(2):109–128.

in the vital statistics offices, and the records of 16,000 of these were found in the VA files, because both members had been in military service.

But which pairs were identical and which fraternal? Fingerprints, obtained from FBI files, were not conclusive, unless buttressed by other information. Blood group matching was an almost certain indicator, but impracticable for 32,000 twins. It turned out that the most efficient method was simply to ask the twins: e.g., "When growing up were you alike as two peas in a pod, or did you have a family likeness only?" The error using that sort of question—as checked by serological tests on a sample of twins—was about 4 percent, or considerably better than the 13 percent error rate with fingerprints and other physical traits. About 44 percent of the 11,510 twin pairs classified to date are identical.

The men who are included in the Registry—beyond the biological differences in twins recounted earlier—are not a representative sample of the U.S. male population: All of the men were selected by the admission processes of the military services in World War II, which, for example, excluded men who had tuberculosis, rheumatic fever, diabetes or other chronic diseases. Nevertheless, the Registry is a unique resource for human genetic studies—pairs of men, some with identical genes and some sharing only half, for whom military records have been reviewed and for whom both mortality experience and VA hospitalizations can be retrieved routinely by computer searches.

Since 1966, investigators, upon approval of their proposals by the NRC Medical Follow-up Agency, have used the Twin Registry, either analyzing the information in files and on computer tapes or, in many cases, doing studies directly with selected twin pairs. The diversity of research, as expected, has been great. The Registry has been used to investigate differences in respiratory and coronary symptoms between smoking and nonsmoking twins, genetic influences in various psychoses, the relative importance of heredity and environment in psoriasis and atopic dermatitis, and the genetics and epidemiology of coronary heart disease.

Direct work with twin pairs helped show that heredity has little or nothing to do with a medical curiosity: an increase in internal eye pressure of some people upon topical application of glucocorticosteroids, such as cortisone. And about 2,500 pairs who responded to a questionnaire, as well as the military records of some 1,000 twin pairs who served in the U.S. Navy, are being used in an effort to sort out the relative contribution of genetic traits, abilities, family structure during childhood, schooling, and other factors on later differences in earnings between twins.

PRENATAL X-RAYS

The Twin Registry is basically a tool for prospective studies, offering a known base that undergoes changes in time that can be tracked. A retrospective study is exemplified by the Medical Follow-up Agency's current investigation of the relationship of prenatal x-rays to childhood cancer, including leukemia.

The first published report that abdominal x-rays of pregnant women appeared to cause an excess of cancers among the children who had been exposed prenatally appeared in 1956. Since then, results of several other studies have been published, some confirming the original report, some failing to confirm it, and some producing very puzzling data. For example, an early study at Oxford University showed an association of premarriage and prenatal x-rays with childhood cancers but not of x-rays between the time of marriage and pregnancy; a Baltimore study found a significant relationship of prenatal x-rays to subsequent mortality from various causes (including accidents) in white children, but not in black children. Some of these and other results have been partly ascribed to the hazards of depending on the mother to remember her x-ray history during her pregnancy and to the statistical fact that prenatal x-rays are more likely to be done in first pregnancies or multiple births or on women coming from particular socioeconomic milieus.

One way to minimize some of these problems is to conduct a study based on medical records, not on interview and recall, of mothers who were all cared for during their pregnancies in a uniform medical system. Those criteria fit mothers of children born in military hospitals.

The names of children who died of cancer when they were 15 years of age or younger were on computer tapes of the National Cancer Institute. Those who had been born in military hospitals were identified from birth certificates on file at the various local vital statistics offices. Once the names of the children and of the military hospitals in which they had been born were known, the hospital records could be obtained. In this way, records were found for 1,044 children who died of cancer. Records for 2,088 controls were obtained from the same hospitals. By fall 1975, all medical records had been abstracted, coded, and stored on computer tape, ready for analysis.

What will emerge is verifiable information about certain environmental and biological factors of possible importance in the etiology of childhood cancers.

Medical Follow-up Agency, Division of Medical Sciences, Assembly of Life Sciences. Director, Gilbert W. Beebe; Associate Director, Seymour Jablon.

BOARD ON MATERNAL, CHILD, AND FAMILY HEALTH RESEARCH

In December 1974 the Assembly of Life Sciences established the Board on Maternal, Child, and Family Health Research to study the long-term effects of developmental processes on the health of the people of the United States. The Board has the following functions:

1. To identify continually the health needs of young persons (infants, children, and adolescents), viewing them as potential parents
2. To extract material on a continuing basis from research reports and national health statistics to: (a) help identify maternal, child, and family health needs; and (b) suggest priorities for improving maternal, child, and family health
3. To maintain broad surveillance of the private and public policies and practices that influence maternal, child, and family health care and research and to provide a forum for discussion and study of change
4. To help direct public and private resources toward a coherent national effort on behalf of maternal, child, and family health

The Board is multidisciplinary and includes members from the fields of behavioral psychology, child development, genetics, internal medicine, law, midwifery, obstetrics, pediatrics, psychiatry, and sociology. Through its members. consultants, and staff, the Board will maintain a general knowledge and establish studies of pregnancy and the perinatal period;

genetic disorders and congenital malformations; diseases and disease patterns; and developmental pharmacology and the use of medical instrumentation or devices.

The new Board inherited the existing Committee on Phototherapy in the Newborn. That Committee was charged with evaluating the safety and efficacy of the use of light energy in treating human disease, and its chief concern was the use of phototherapy to treat hyperbilirubinemia in newborn infants. The Committee produced a Preliminary Report, a Final Report, and a book entitled *Phototherapy in the Newborn: An Overview,* which is a selection of papers presented at a symposium in February 1973 and additional papers prepared by various members of the Committee.

A second activity inherited by the Board was the Committee for the Study of Inborn Errors of Metabolism. That Committee was established to develop an effective program for dealing with inborn errors of metabolism as a single and identifiable but multifaceted health problem of national importance. The Committee was asked to examine the origins, history, and current standing of screening for phenylketonuria (PKU) and the effectiveness of PKU treatment and to extend its purview to encompass screening for other genetic diseases and characteristics. This latter charge was interpreted broadly to include a study of the relationship of genetics to preventive medicine. The committee has completed its charge and in 1975 produced a final report entitled *Genetic Screening: Programs, Principles, and Research.* Two sections of the report were excerpted and printed in a pamphlet, *Genetic Screening: Procedural Guidance and Recommendations.* A third publication, *Genetic Screening: A Study of the Knowledge and Attitudes of Physicians,* reports on the results of a study conducted under the aegis of the Committee.

The Committee for a Study for Evaluation of Testing for Cystic Fibrosis is the third activity inherited by the Board on Maternal, Child, and Family Health Research. That Committee was asked to study the following aspects of cystic fibrosis, of both practical and theoretical importance:

1. The reliability of the data on "cystic fibrosis factors" in serum and in tissue-culture fibroblasts with respect to the diagnosis of cystic fibrosis in the homozygote and heterozygote in intrauterine life, infancy, and childhood

2. The evaluation of the ciliotoxic factor in serum and in tissue-culture media as a diagnostic tool

3. The evaluation of the various screening tests for cystic fibrosis in the newborn that have been proposed, both in this country and abroad, but about which there is considerable controversy

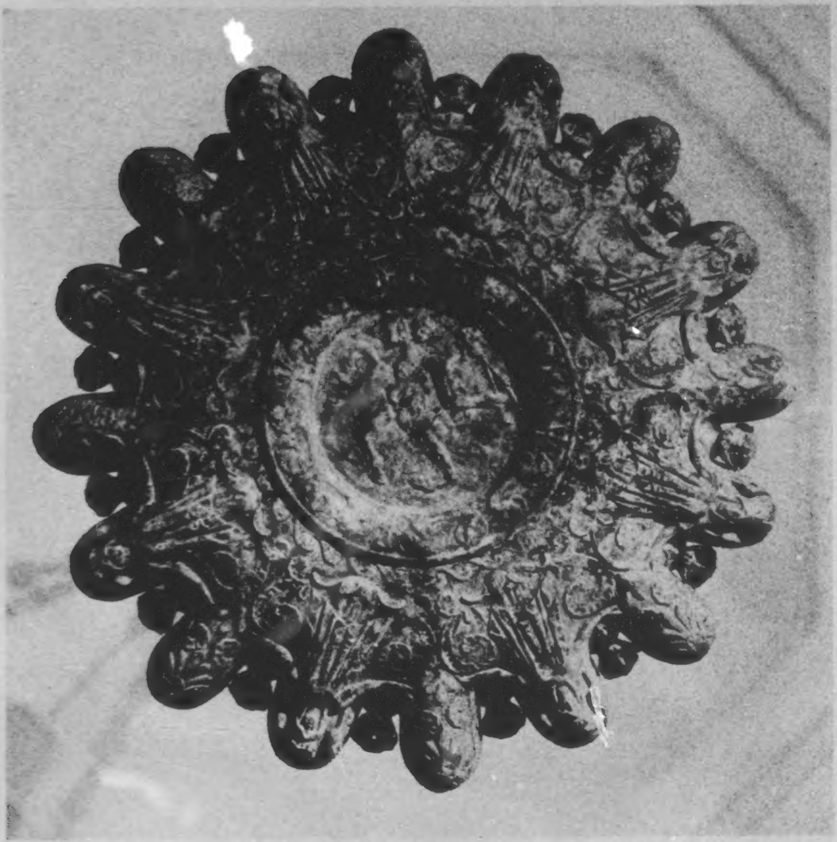
4. The evaluation of the "sweat test," which is not being performed properly in most hospitals throughout this country, leading to many errors in diagnosis, both positive and negative

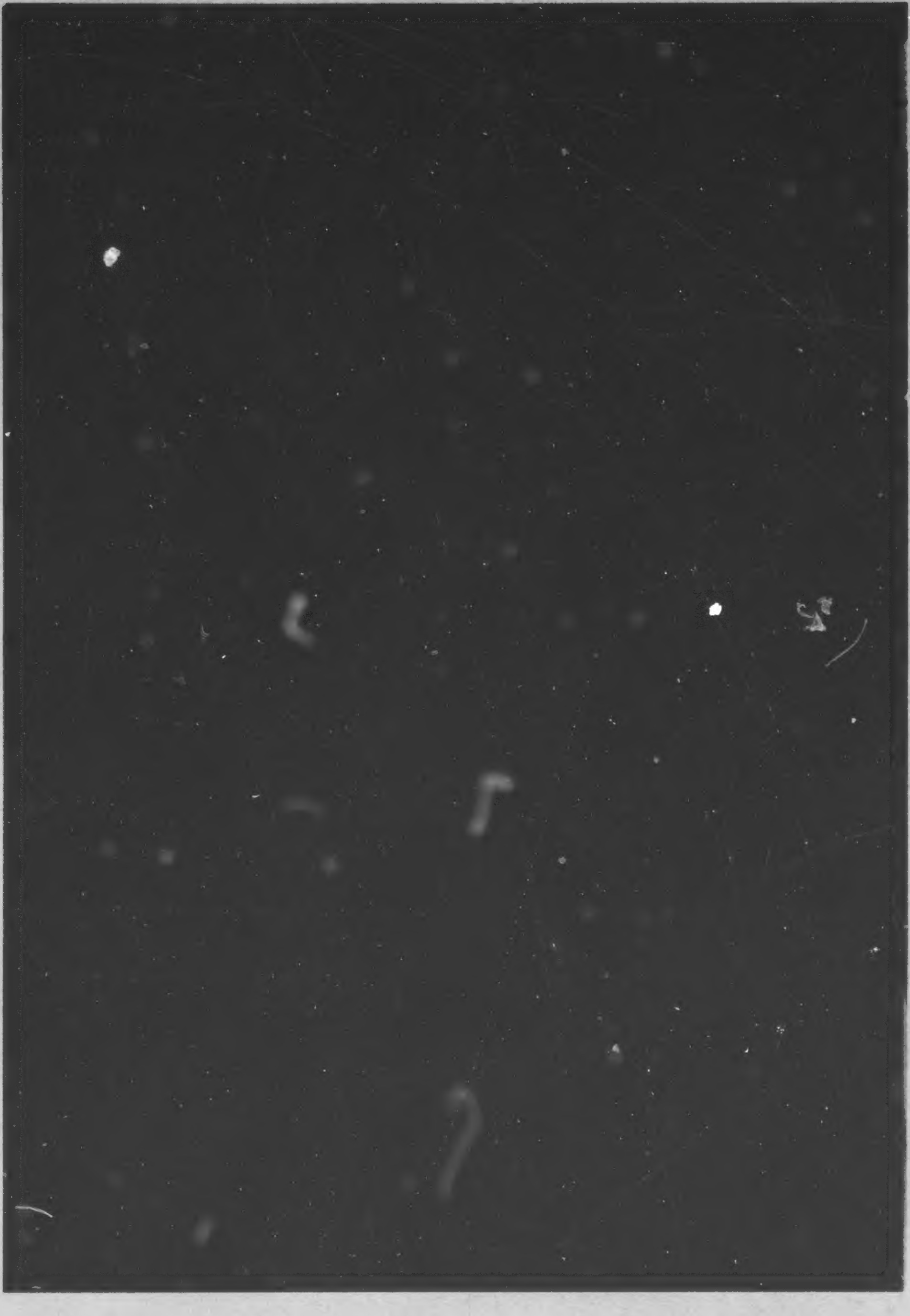
The Committee for a Study for Evaluation of Testing for Cystic Fibrosis has finished its work, and its Final Report is to be published in April 1976.

In addition to overseeing the three established activities, the Board on Maternal, Child, and Family Health Research has initiated two new committees. The first is the Committee on Maternal and Child Health Research, and its charge is consistent with all four functions of the Board. Funded by the National Institute of Child Health and Human Development of the National Institutes of Health, the Committee is conducting a study and review of research and research training programs in maternal and child health supported by the health component of the Department of Health, Education, and Welfare. The study will include research and research training programs, funded over the past 3 to 5 years, whose object is the improvement of the health of mothers and children. The purpose of the study is to identify gaps in research on maternal and child health and to recommend priorities and directions for future research that will enable the National Institute of Child Health and Human Development to carry out its charge. The Committee is multidisciplinary. Special attention is being given to research in endocrinology, genetics, human embryology and development, and reproductive biology.

The second new Board activity is the Committee on Implications of Declining Pediatric Hospitalization Rates. While little information is available regarding pediatric hospital bed occupancy rates, they appear to be both lower than rates for the general hospital population and declining. Low bed occupancy rates in pediatric wards have important implications for the organization and delivery of health services for children. Low rates may also affect the quality and cost of care and the quality of training for residents. The Committee on Implications of Declining Pediatric Hospitalization Rates will review current knowledge of the problem, provide suggestions for improving the recording of data on pediatric hospitalization rates, and recommend ways to plan for more effective utilization of available clinical resources for both inpatient and outpatient pediatric care. The Committee is funded by the Bureau of Community Health Services, Department of Health, Education, and Welfare.

Board on Maternal, Child, and Family Health Research. Division of Medical Sciences, Assembly of Life Sciences. Board Chairman, Alfred G. Knudson, Jr., of the University of Texas Health Sciences Center; Executive Director, Artemis P. Simopoulos.





LESTER B. LAVE
Acting Chairman (December 1974 through May 1975), Assembly of Behavioral and Social Sciences

Assembly of Behavioral and Social Sciences

6

Social Issues and Social Research

If we used the Chinese calendar, 1974 would have been the Year of the Lawyer and 1975 the Year of the Economist; both subjects are represented in the work of the Assembly of Behavioral and Social Sciences. While such intellectual aggrandizement is usually met with stout resistance, I found that my natural science and engineering colleagues were happy to give us the responsibility for these years. But 1974 and 1975 were not totally without redeeming features. Events during those and earlier years demonstrated society's need for answers to many social questions and sparked social experiments, new theories, and new analyses—all in an atmosphere of discovery and excitement normal to periods of iconoclasm.

The inadequacies of the older theories of the social and behavioral sciences include too little attention to the actual behavior of individuals, a neglect of dynamics (since comparative statics seemed to be adequate), and a poor data base analyzed inadequately.

The 1974–75 recession–inflation is an exemplary case. Almost two hundred years ago, Thomas Malthus and David Ricardo debated whether depressions and unemployment were interesting questions for economics. Malthus pointed to the resulting hardships and widespread interest in these phenomena; Ricardo argued, from the viewpoint of comparative statics (the set of tools then available), that depression was but a brief interlude in the passage from one equilibrium to another. Ricardo won, as generally happens when current methods are not adequate to handle real problems. Economists did not seriously examine depression until the 1930s, when J. M. Keynes developed a comparative statics model that apparently had a high unemployment equilibrium. Whether or not the model performed as claimed, Keynes' *General Theory of Employment, Interest, and Money* was a major stimulus to research. Keynes' insights were explored and formalized in the 1940s and 1950s. But in the late 1960s the underlying structure of the economy changed, and the Keynesian theory progressively lost its power to explain what had occurred and to forecast what would occur. One reason for the failure was that Keynes' *General Theory* was based on conditions in Great Britain in the 1930s. A more important reason was the continued reliance on equilibrium models at a time (1968–1975) when governmental policies and worker and consumer expectations changed so rapidly that we were in continual disequilibrium. The result has been a chastened set of economists and some very exciting new research.

A second factor catalyzing the current ferment in the social and behavioral sciences is that we allowed our good names to be used in support of programs lacking both a theoretical and an empirical base. To most people, President Johnson's "Great Society" programs were "social engineering"—the payoff from the work of the social sciences. Nothing was further from the truth. The Great Society programs and social experiments spawned much good research; but the social sciences were not, and may never be, in a position to design such large changes in the social fabric as envisaged in Great Society programs. We are good counter-punchers: good at critiquing a proposal and discerning its implications. But we do not have the knowledge to design society-wide programs with predictable consequences.

These criticisms of the social and behavioral sciences—deficiencies of fundamental theories and methods and perceived responsibility for the failures of massive social programs of the federal government—come at a time when society is in a mood to question the utility of government expenditures on research, with social science research as the opening wedge. The social sciences are particularly vulnerable to attack since they examine the behavior of man (disproving long-accepted beliefs is never popular, as Socrates could testify) and since the accumulation of data and knowledge in social research is not as straightforward as in physics or chemistry. Results are often situation-specific, and the contribution to general knowledge and theory from each individual piece of research may be quite small. And, occasionally, a fundamental shift in social institutions may vitiate, or seriously qualify, a successful social science theory —e.g., the situation of macroeconomic theory in the 1970s. Even the best social science theory is often on one horn of a dilemma: rigorous, but irrelevant; or relevant, but hardly scientific.

But, however justified these criticisms, understanding individual behavior and social interactions is crucial to formulating sensible policy. If one accepts the notion that these ought to be studied scientifically, one is committed to supporting the social sciences in principle, even if some individual projects are apparent nonsense. But this discussion is more apologetic than is warranted. No matter how many ashes we economists have heaped on our heads, postwar economic history, including that of the 1970s, has been prosperous and stable compared to earlier periods. Modern economic advice may not have worked as well as promised by the phrase "fine tuning," but it worked better than its predecessors.

SOCIAL SCIENCES R&D

Criticism prompts stock-taking; and the Assembly's Study Project on Social R&D is indeed taking stock of social R&D under way or planned within the federal government and of its possible relationship to the making of policy. The Study is funded by the Science and Technology Policy Office of the National Science Foundation, and is discussed in more detail on pages 76–81 of this report. On its agenda are questions such as: What social research and development is currently being done? What determines how these problems are defined and how much research takes place? How does social R&D become decision relevant? Indeed, what *is* decision relevance? Our new Committee on the Social Sciences in the National Science Foundation is a related effort and will make use of much of the work of the Study Project.

As one might guess, these committees have raised major issues concerning the support of the social sciences and the use of the social sciences in policymaking. To be more specific, in fiscal year 1975, approximately

$1 billion was spent by the federal government on what might loosely be called social R&D, with half spent by HEW. Of the $1 billion, about $100 million went to peer-reviewed unsolicited proposals, with the remainder going to projects *not* peer-reviewed by outside scientists. The latter investment may be less than totally productive. Often a large project is divided into design, data collection, and analysis, each requiring a separate Request for Proposal (RFP) stipulating a short response time, a brief period to do the work, and closely (sometimes incorrectly) specified tasks. Such procedures mean that the projects are essentially closed to university researchers and may indeed—because continuing support for personnel is not assured—rule out the participation of *any* legitimate research organization.

The Assembly's study of social R&D also makes it apparent that there is only the loosest of connections between social science research and decision making. A careful scrutiny of decision making reveals a series of factors necessary if research is to be decision relevant. For example, to fit the crisis nature of much decision making, a theory must be fully developed and tested, applications must be explored in detail, those giving the advice must have the proper credentials and be able to communicate the results, and the results should be complete or completable on short notice. These criteria explain why social science research has not been more closely linked to policy. By the same token, they pose the interesting question of whether (and how) research can be made more decision relevant.

IMPROVING OUR UNDERSTANDING OF SOCIAL PROCESSES AND PROBLEMS

In addition to such questions of grand strategy, the Assembly is focusing on several areas where it appears fruitful to apply current knowledge to pressing social issues. One is human development. Committee activities include a study of child development, an evaluation of manpower R&D in the U.S. Department of Labor, an evaluation of vocational education R&D, and an evaluation of the effort to decentralize federal manpower training and employment programs by transferring them to state and local governments. Two proposed studies of particular interest are an examination of the criminal justice system and an investigation of the transition from school to work.

Human Development

Studies of economic development make it clear that the most important economic resource—perhaps the only indispensable resource—is "human capital." This resource is more important to the prosperity of nations than mineral resources, climate, or material wealth. It is a safe prediction that the nation that gets the most out of its people—i.e., the nation in which human development flourishes—will be the richest nation in the twenty-first century, regardless of mineral resources or climate.

But human development issues are inevitably complicated. At the broadest level, there is little controversy, but also little content. Clearly, the family is the predominant influence on child development; and children develop their full potential in a stable, loving, and stimulating family environment. But if the family environment is less than ideal, are there compensatory programs that can bridge the gaps? Will improved welfare programs and a better array of social services improve the family environment and, by implication, a child's development?

In attempting to avoid the contentless generality of talking about ideal family environments, many researchers have limited their scope too severely. Often it is as unproductive to take a narrow problem as to try to solve the most general one. Crime is a good example because it is an important social problem and researchers have tried to take a narrow approach to reducing the symptoms. For example, crime was found to be lower in areas with more street lights and police. Unfortunately, policymakers tried to apply these findings by putting up more street lights and expanding police forces. As a good systems analyst would have predicted, crime increased in the unlighted places and in the suburbs, with their smaller police forces. While there has been a slight overall reduction in crime because of the lights and police, the major effect has been to shift crime to places where there is less chance of being caught.

A thought-provoking observation related to the issue of human development and criminality is that the proportion of the population incarcerated in such countries as the United States, Canada, and Norway has been constant for as long as they have had the statistics. Apparently, a law-abiding society, such as Norway, jails people for minor crimes, such as driving with a blood alcohol level we would consider absurdly low, while a violent one, such as that of New York City or the District of Columbia, might reserve prison for major crimes of violence. This observation suggests that deep social principles govern criminal justice systems and that failure to uncover these will mean that many plausible solutions will turn out to be incorrect or even perverse.

Income Potential: Burglary versus Dishwashing

One heresy that we economists indulge in is modeling decision making as if it were rational. Even our social scientist colleagues regard this as absurd. But the exercise is instructive. Consider the teenager deciding between a legitimate job and a life of crime. Ignoring the disutility of being incarcerated, the first variable in the decision is the expected lifetime income of each choice. For a black, male teenager in a large city, burglary offers a much higher lifetime income than unskilled labor, and the crime rate among black teenagers reflects that fact. That this model correctly predicts a high crime rate among poor, unskilled teenagers is hardly a powerful insight. But the model does make clear that both carrots and sticks can be used to decrease the crime rate. In the past, the sticks have been emphasized: Increase the probability of arrest (more police), the probability of conviction (no-knock laws, wiretapping), and the period of incarceration (no suspended sentences, no parole, longer sentences). Clearly, such measures could succeed in reducing the crime rate, but only at the cost of fundamental and deplorable changes in society. The carrot tactic has received little emphasis: Lower teenage unemployment (currently over 60 percent for black teenagers in some cities), provide training and generally increase educational opportunities, and ease the transition from school to work to reduce unemployment or trauma. Assembly committees and proposed projects in the human development area might be viewed as focusing on carrots and sticks, particularly on the carrots that can enhance human development, thereby making criminal activity less attractive.

STRAINS ON SOCIAL INSTITUTIONS

One of the most fundamental problems to which the Assembly has attempted to apply the knowledge of the social sciences is the strain on social institutions. During the past decade, there has been increasing pressure on and dissatisfaction with social institutions. The environmental movement, criticism of science and technology, and widespread criticism of regulatory agencies are a few of the manifestations. One predictable reaction by the federal government has been to turn many of these touchy issues over to blue-ribbon commissions and committees—hence the increased business for the National Research Council.

The Assembly's activities reflecting this increase include the Committee on the Societal Consequences of Transportation Noise Abatement (discussed on pages 81–84) and the Assembly's recent report examining the economics of outdoor recreation resources, especially the measurement of the social demand for these resources. Response to the increased pressure on social institutions has also generated proposals for new activities by the Assembly.

Social and Psychological Consequences of Economic Uncertainty

It is hard to overstate the concern of Americans with "double-digit" inflation. Economists are particularly surprised by this concern since wages are generally linked to the inflation rate. Is there a "money illusion"? Does high inflation introduce so much uncertainty that consumers feel worse off than they really are? Or is the perception valid, because the assets of Americans actually are eroded significantly by high inflation? The question deserves attention.

Market versus Nonmarket Allocation

During the 1973 Arab oil boycott, the supply of gasoline fell. Rather than allow the market to allocate the smaller amount of gasoline, the government indulged in measures that rationed gasoline, with resultant lines at gas stations. Time, not dollars, became the necessary resource for getting gasoline. A study proposed by the Assembly would examine what the characteristics are of various ways of allocating goods. When is market allocation preferable? When is rationing-by-coupon preferable? When is an informal rationing system—e.g., queuing for gasoline—preferred? The answers depend on what the goods are needed for, the degree of curtailment, the distribution of income (and wealth) in society, and the extent of the public understanding and sympathy with the cause(s) of the shortage. Answering these questions requires a broad mix of disciplines and a good deal of evidence, and it is high on our list of proposed studies.

Conflict Resolution and Avoidance

Conflict generally does not lead to violence. Society has many informal and formal means for resolving conflict; and, perhaps more important, for avoiding conflict. While considerable work has been done on the resolution of conflicts, more attention should be given to conflict avoidance and to redefinition of the questions worth exploring.

ASSEMBLY MANAGEMENT

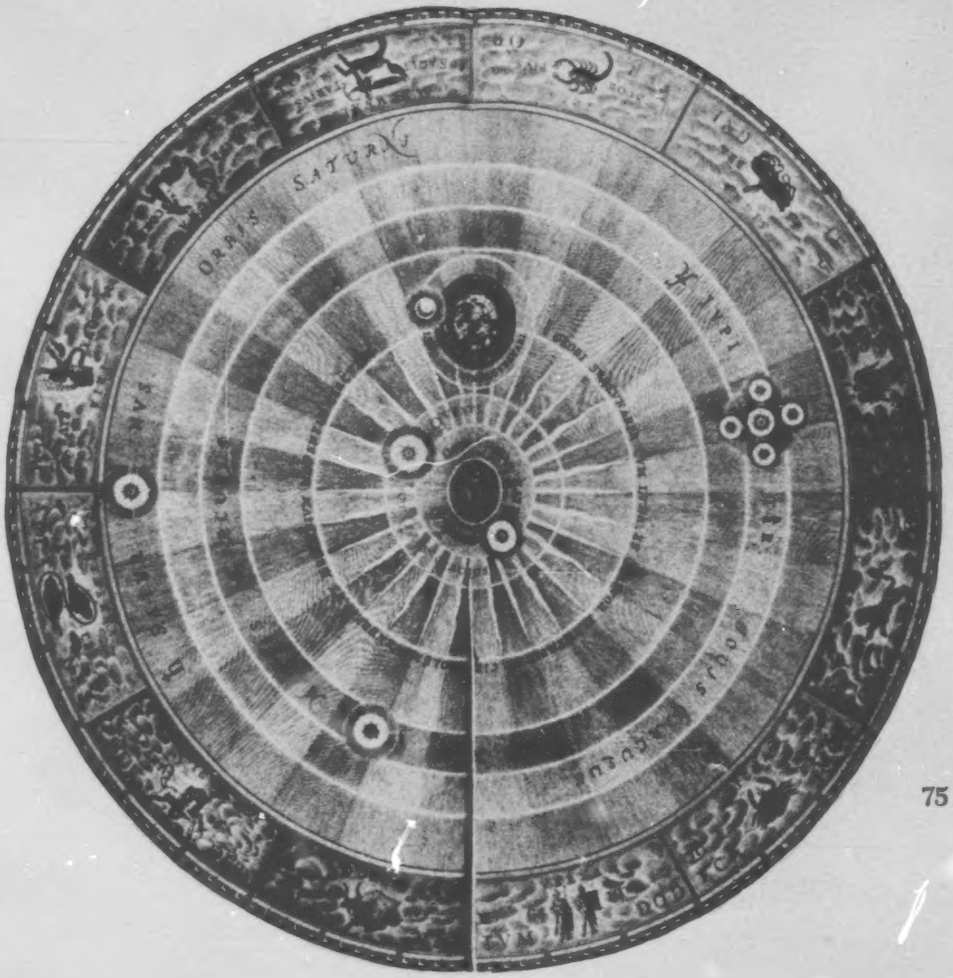
These problems and our attempts at applying social science knowledge to them are our reason for existence. But these high purposes can be served only when the Assembly is organized to appoint and help committees and when it has sufficient funds to plan projects. The Assembly has been fortunate to obtain grants from the Ford and Russell Sage foundations to fund program planning. These funds give us the ability to explore ideas and develop them to the point that government or foundation support can reasonably be sought. Thus, rather than reacting only to the requests of agencies and foundations, the Assembly attempts to identify problem areas and promising projects.

The Ford and Russell Sage grants and the consequent financial ability to plan and develop programs enormously increased the demands on the staff; senior staff time, not money, became the limiting factor on our activities. Thus, there is particular significance in the recent additions to the Assembly staff of an associate executive director and an editor/reports officer.

Finally, if one took a limited view, it would be easy to complain about the staff time required for NRC-wide activities: the Analytical Studies for the U.S. Environmental Protection Agency, the World Food and Nutrition Study requested by President Ford, and the Study of Nuclear and Alternative Energy Systems. But, aside from the obvious benefit of a catholic examination of major and complex problems, these studies have the more subtle benefit of increasing interactions among Assemblies and Commissions and thus decreasing the categorical isolation of NRC activities.

The reorganization of the NRC brought new challenges to the Assembly; the Ford and Russell Sage program planning funds enabled us to put more time and thought into new projects. With many of the organizational problems now under control, we look forward to a more aggressive search for activities that would uniquely benefit from an NRC study.

LESTER B. LAVE



7

Study Projects

STUDY PROJECT ON SOCIAL RESEARCH AND DEVELOPMENT

For several years, senior government officials and members of Congress have expressed serious reservations about the numerous research and development programs addressed to social problems. Of concern has been the alleged low quality of the work produced by these programs and the limited value of even the competently performed R&D in the formulation of social policy. Important problems that are the joint responsibilities of several agencies seem to receive little attention. Decision makers, such as officials in the Office of Management and Budget, have not even been able to get a clear and concise picture of the extent and nature of support for social R&D. The Study Project on Social R&D was funded by the Science and Technology Policy Office of the National Science Foundation to examine the social R&D enterprise, to investigate the merit of these concerns, and to make recommendations for improvements in the organization and management of the federal support of social R&D.

WHAT DO WE MEAN BY SOCIAL R&D?

Social R&D consists of research and development aimed at understanding and alleviating social problems. It is not solely research carried on by social and behavioral scientists, although virtually all of it involves these disciplines. As the committee overseeing this work attempted to identify and classify social R&D programs, it discovered a number of significant "gray areas," including

- Biological, clinical, and related research, such as that supported by the Alcohol, Drug Abuse and Mental Health Administration and NIH
- Hardware development that could be used for social purposes, such as those of the Department of Defense, Department of Transportation, and the Energy Research and Development Administration

In general, the committee tried to exclude purely chemical and biological studies, such as those aimed at developing new drugs, and technological projects, such as demonstrations of new transportation systems. However, the boundaries of social R&D still remain unclear.

Another difficulty in classifying R&D programs is determining what is truly research and development. Should policy analyses or program evaluations be included? Should the collection and analysis of social statistics be considered social R&D? Are demonstration projects a part of the social R&D enterprise? In general, the committee has been inclined to include these since each of them is perceived by the Congress and the public to be social R&D and since each makes heavy use of social scientists and social science methods of inquiry.

AN INITIAL MAPPING OF SOCIAL R&D EFFORTS

The committee first compiled an inventory of social R&D activities currently being carried out by major agencies of the federal government. Interviews were held with policy and administrative personnel and budget data were collected on social R&D activities. Some significant points emerged:

- Social R&D, even by conservative definitions, is a large enterprise, totaling over $1 billion annually.

- HEW is responsible for some 50 percent of social R&D.
- Social R&D is spread over an extremely large number of agencies, particularly since in many departments and agencies funds are further divided among more or less autonomous bureaus or institutes.
- Research, both basic and applied, constitutes more than one-third of the effort, about the same as the proportion for all federally supported R&D.
- Development, as it is understood in technological areas, is apparently not done and is "replaced" by experiments and demonstrations. (A minor exception might be curriculum development at the National Science Foundation, the National Institute of Education, and the Office of Education.)

The committee examined the allocation of resources for social R&D by problem area and noted that

- 37 percent of social R&D is allocated to education and manpower although these activities constitute less than 5 percent of total federal domestic expenditures (and less than 10 percent of federal domestic expenditures if income security is excluded).
- Expenditures related to individuals (health, education, manpower, social services, income security) are 2.5 times greater than those focused on communities (public safety, housing, community development, transportation, environment, economic development, governance).
- 67 percent of health-related R&D is classified as research, while only 17 percent of education R&D is so classified.

These observations and many others reinforced the committee's view that data on social R&D expenditures were not organized in a manner that allowed systematic evaluation. This initial inventory of federally supported social R&D provided the background for consideration of the usefulness and relevance of social R&D to the formulation of social policy and the organization and management of the social R&D enterprise. The second phase of the project was therefore designed to address issues such as the following:

- What are the proper functions of the social R&D enterprise? How is and how should social research and development be used in policymaking? What is a meaningful definition of policy relevance?

- Are there preferred means to organize and manage federal support of social R&D? How should nonresearch persons be involved?
- Does the current organization of the federal government mean that some questions or functions receive too little attention? Does research that crosses agency jurisdictions get slighted? Is too little attention paid to the use of R&D?
- Would the enterprise be improved by some form of overarching policy structure (perhaps orchestrated by the Domestic Council or the President's Science Advisor)?

In short, the committee is seeking to establish the dimensions of science policy in the social areas and to make recommendations for improvements in this policy.

SUPPORTING STUDIES

The committee staff, with the assistance of consultants, is preparing papers on several of the problems raised above. For example,

- A series of studies are examining how federal agencies organize and manage social R&D related to the living environment (Agriculture, HUD, DOT, EPA, and Interior), to income security (HEW, Agriculture, and HUD), and to health services (primarily HEW). Two studies also focus on research relevant to target populations: the aging and young children. These studies are seeking to identify the determinants of the character of current federal programs in these areas. Who sets priorities? Who selects performers? How is the use of R&D findings promoted? Is there any coordinated planning of research?
- A number of studies of important management processes are under way. The grants and contracts policies of several departments have been examined, as well as innovative ways to improve the definition of projects and the selection of performers. In addition, the planning processes of a number of agencies are being examined, since early observations suggest that little real planning takes place outside of the normal

budget planning. The research on knowledge utilization is also being reviewed.

- A number of papers relating to the use of social R&D in policy-making have been commissioned.
- A study of the planning and management of longitudinal data bases has been commissioned. Particular emphasis is being placed on means for facilitating their use in research.
- Studies of the history of the development of modern demography, survey research techniques, and negative income tax proposals have been commissioned. These studies focus on the nature of the financial support for critical events in these historical examples as well as their institutional context. They are intended to provide insight into strategies for the support of social science inquiry.
- A study of the use of econometric and demographic methods to forecast emerging social problems as a basis for planning programs of research is under way.
- A broad history of the growth of social R&D has been commissioned.

The report, to be issued in September 1976, will be substantially concerned with applied work, since less than 10 percent of social R&D expenditures support basic research. It will focus primarily on improvements that involve several agencies (grants and contract processes, for example) rather than dealing with specific programs. While the setting of priorities for research on particular problem areas is beyond the scope of the committee's assignment and capabilities, the report should propose better procedures for grappling with this issue. In particular, it will include

- A discussion of the process by which society deals with problems, with the intent of highlighting the manner in which social research and development might contribute
- A careful consideration of the functions that social R&D should be expected to perform
- A discussion of the current organization and management of the federal support for social R&D, together with recommendations for improvements

In sum, the hope is that this study will provide a clearer picture of the social R&D enterprise and establish the terms of the debate over its future directions.

Study Project on Social Research and Development, Assembly of Behavioral and Social Sciences. Chairman, Donald E. Stokes of Princeton University; Study Director, Thomas K. Glennan, Jr.

SOCIETAL CONSEQUENCES OF TRANSPORTATION NOISE ABATEMENT

The major purpose of this study—part of the series of NRC studies for the U.S. Environmental Protection Agency (see page 121)—will be to estimate the costs and benefits to society of the reduction of transportation noise and to suggest feasible combinations of costs and benefits as a guide to establishing policy.

There are three major ways to reduce transportation noise:

- Influence the sources. For example, engineering modifications can be made on motor vehicles, airplanes can be retrofitted with sound-deadening devices, noise operation standards can be applied to the manufacture and maintenance of new transportation vehicles. Alternatively, use of transportation vehicles can be curtailed, the vehicles can be run at lower speeds, or larger-capacity vehicles can be substituted for smaller ones.
- Influence the receivers of transportation noise. Through the use of insulation, new building materials, and noise-muffling design, the effects of a transportation noise may be reduced.
- Without changing either source or receive[illegible] shift their relative locations so that noise receivers are under less liability from the sources. Highway and traffic can be rerouted; new airports can be located farther away from metropolitan centers.

COSTS

For each of these three strategies, whether pure or mixed, the direct costs of applying the strategy to the estimated transportation noise from each source can be calculated. There will also be indirect costs. If, for example, lowering speed limits would reduce motor vehicle noise, the cost of truck delivery would increase, which would increase the cost of the goods to consumers. Such charges, as well as abatement procedures that increase fuel consumption, have to be calculated and added to the direct costs.

However, noise reduction may at times actually save money for certain sectors of the economy. For example, one strategy for reducing the noise of diesel trucks operating at highway speeds would be to put a speed-governed clutch on their radiator cooling fans so that fans switch on only at low speeds. The fuel cost saving from the use of such clutches might, over a 1- or 2-year period, outstrip the cost of the clutch installation. The fuel-cost savings could be considered a benefit, or it could be treated as a negative cost subtracted from the positive cost of installation, yielding a self-contained treatment for a particular abatement strategy. Such organizational decisions have an influence on the conceptualization of the cost–benefit structure. Certain important factors, such as the change in land values, can be assigned to the appropriate category—costs or benefits—only after they are computed.

Even after they are classified and quantified, all costs are still not equivalent. Some are levied on different constituencies: airlines, trucking industry, consumer, and so on. Some are short run, others long term; some are localized, others distributed. A series of explicit value assumptions will have to be made in order to aggregate or summarize these different aspects of costs.

Since each possible abatement procedure results not in one level of noise reduction but rather in several levels, depending on the extent to which it is employed, the determination of costs is a function of the amount of abatement or of the final noise level desired. Differing strategies of noise reduction will be differentially efficient, and differing projections of future transportation use will each have different associated costs.

BENEFITS

Almost all the problems and issues raised in estimating the costs of noise abatement reappear, and in many ways are magnified, in a discussion of benefits. As with costs, recipients of the benefits will have to be identified, as they form several different constituencies. For example, the benefits for transportation workers—ground crews, truck drivers, and the like—will differ from those for suburban homeowners or city workers and residents.

For each group there are roughly three kinds of possible benefits:

- Medical and physical benefits, such as reduced hearing loss, fewer heart attacks, and improved health, which can be somewhat quantified through conventional insurance or workmen's compensation estimates
- The reduction of transportation noise, which might well increase productivity directly or reduce waste and error (although the data are scanty on this point, productivity increases can, in principle, be converted to the same monetary units as costs)
- Quality of life

This tripartite division is not to imply that these three aspects are independent. For, clearly, medical disability implies both loss of productivity and diminished quality of life; similarly, productivity loss may impair general health or poor quality of life may diminish productivity The last factor, quality of life, is the nub of the study. Through social indicators, surveys and other diverse sources, some attempt will be made to correlate levels of annoyance, dissatisfaction, and discontent with current noise levels and the changes in these indicators as the noise is abated. At present, current legislation, executive rulings, and safety codes tend to discount such concerns, possibly because of lack of adequate information about quality of life, the difficulty of quantifying what information is available, the ambiguous legal status of pertinent rulings and codes, and a belief that only possible medical disability is a valid concern for regulatory action on the part of legislative groups.

Benefits are, in a manner similar to costs, a function of the degree of abatement desired, the strategy chosen, and the projection of future transportation use. The immediate comparability of these two components—costs and benefits—depends upon successful acceptance of the quantification of the quality of life into units comparable to those used to describe costs.

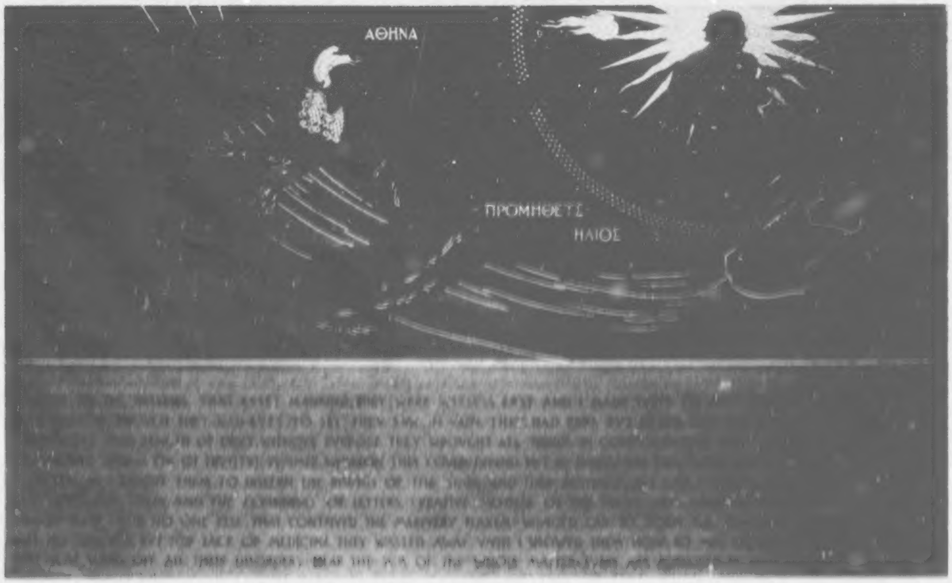
Because the data for assessing quality of life are incomplete, inferences have to be drawn from the relevant psychological, sociological, and social indicator literature as well as from testimony and reports, such as the 1975 Occupational Safety and Health Administration's inquiry hearings into industrial noise standards.

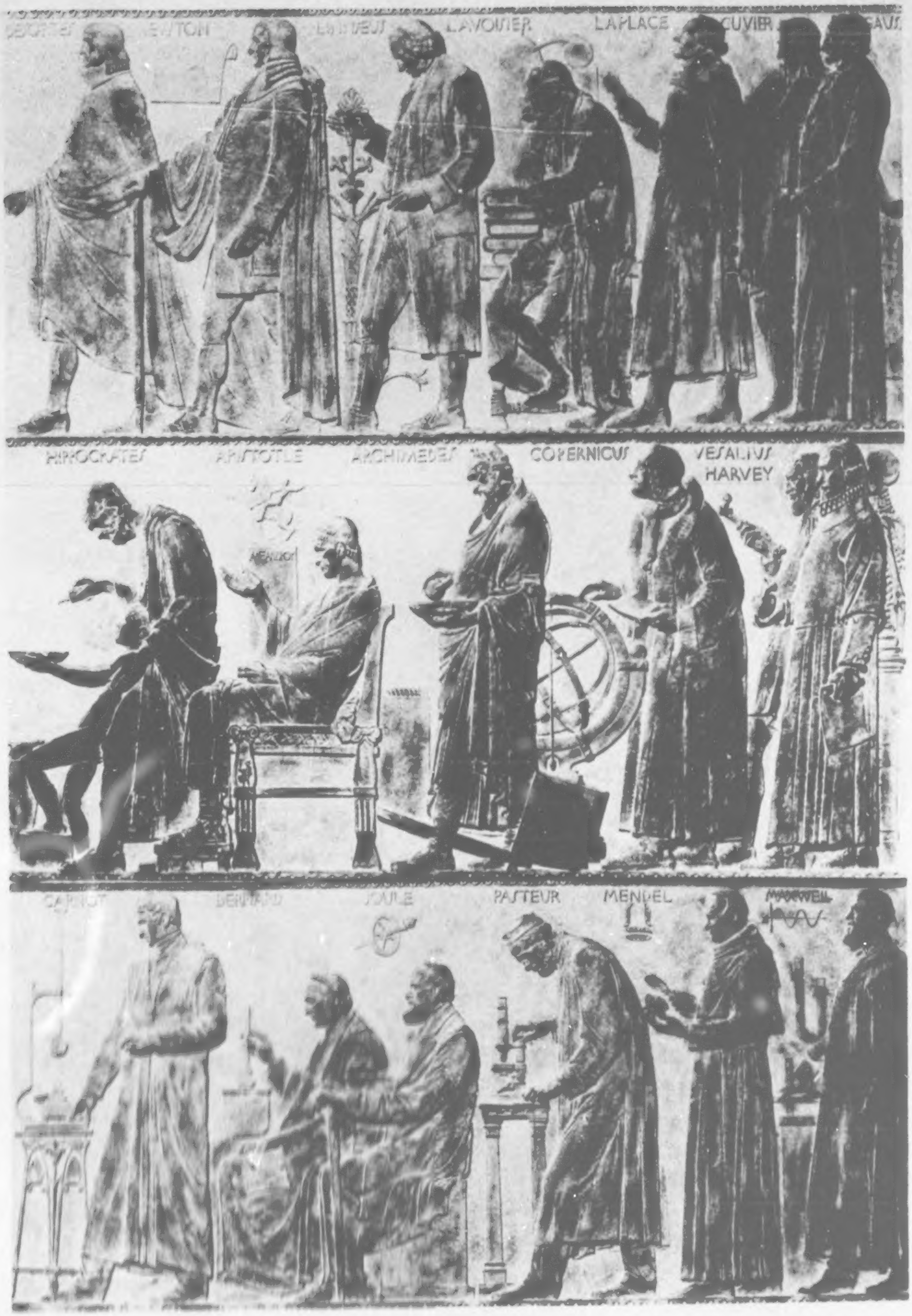
COMPARISONS OF COSTS VERSUS BENEFITS

Although in theory such comparisons should be possible by superimposing the hypothetical graphs of abatement versus costs and abatement versus benefits, it is more than likely that some more explicit statements and nonmetric comparisons will be necessary, particularly if the benefits are not quantified or are in units not commensurable with the costs; e.g., the quality of life will probably not be expressed in dollar units.

In addition, the committee cannot ignore legal and political implications of what are sure to be regarded as recommendations for action. Jurisdiction, public temper, political realities, and flexibility of action are other considerations necessary to completing the study.

Committee on Appraisal of Societal Consequences of Transportation Noise Abatement, Assembly of Behavioral and Social Sciences. Committee Chairman, William Baumol of Princeton University and New York University; Staff Officer, Jerome E. Singer.

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MAXWELL

NORRIS E. BRADBURY
Chairman, Assembly of Mathematical and
Physical Sciences (1974–1976)

Assembly of Mathematical and Physical Sciences

8

Beyond Plate Tectonics

The program of the Assembly of Mathematical and Physical Sciences (AMPS) is both challenging and bewildering in its range and complexity. For example, the issues considered in 1975 included scientific priorities for the nation's space program, the state of catalysis research, the likely effects of subsonic and supersonic jet aircraft emissions on the ozone layer, and probable reasons for differences in skin cancer statistics.

An essay on the state of the mathematical and physical sciences that does full justice within the allotted space to that diversity of interests seems a presumptuous and probably impossible task. A more reasonable approach is to choose one subject within the AMPS ambit and describe its state, including what we would like to know about it and why that might be useful, both to science and society. This year, that subject is geodynamics. According to a nineteenth century definition, geodynamics is the study of the forces and processes that occur inside the earth. It still means that, although the emphasis of geodynamics research over the past several years has been on the mechanisms of the plate tectonics concept and its implications regarding surface and near-surface phenomena.

The late Harry Hess introduced the concept of sea-floor spreading in the early 1960s, and the phrase itself was introduced a year later. Independent observations—seismic, topographic, geomagnetic, heat flow, isotope ages, drilling in ocean sediments—supported the concept and led to the broader model of plate tectonics.

The idea seems simple enough: The earth's outer shell is divided into a small number of large movable and rigid plates each about 100 km thick that form the earth's lithosphere. These plates are created by magma, or molten rock, welling up at oceanic ridges or rises, the junction of two plates. As the process continues, the older crustal material of the two plates moves laterally apart. Since there is convincing evidence that the surface area of the earth is not increasing significantly, the creation of new crustal material in one region implies that older material must be destroyed in another. These older portions of the plates may disappear in subduction zones, associated with Benioff zones—inclined planes of earthquake foci characteristic of many island arcs, the adjacent volcanic areas, and deep ocean trenches. They may creep beneath continental land masses, such as the Andean coast of South America, to create a tectonically active region marked by earthquakes, mountain building, and mineralization. Plates may also rub against each other, as along the San Andreas Fault, creating lateral displacements of tens to hundreds of kilometers over time.

We can use the plate tectonics model to explain why most earthquakes occur where they do, and why, for example, the San Andreas Fault is marked by shallow earthquakes (one plate rubbing against another) and why some quakes in the Aleutian Arc are deep (one plate diving beneath another).

The principles of plate tectonics can also be used to explain how known mineral deposits were formed, and, by analogy, to search out similarly formed, but undiscovered, deposits. For instance, as described by Patrick Hurley [*] of the Massachusetts Institute of Technology, the formation and the location of the immense Troodos copper deposits in Cyprus, the Andean porphyry copper deposits, and the lead–zinc mines in British Columbia can now be rationalized by tectonic events at plate margins. Put very simply, for the Troodos copper, the fundamental event was probably the thrusting of a spreading ridge into a continental block; for the porphyry copper, the subduction of a plate beneath a continental mass,

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[*] P. M. Hurley. 1975. Plate tectonics and mineral deposits. Technol. Rev. 77(5):15–21.

followed by melting, volcanism, and erosion; for the British Columbia minerals, the venting to the surface of sulfides at the edges of volcanic arcs formed by a subducting plate.

The actual analysis is very complex. But Hurley points out that plate tectonics is now a very real prospecting tool. For example, he notes that the "association of porphyry coppers with subduction zones is so evident that prospecting has relied on this fact, and a number of new major deposits have been found in regions that would never have been prospected before. Examples are in East Asia, Iran, Puerto Rico, and British Columbia." [*]

What makes these applications of the plate tectonics model particularly exciting is the fact that the idea itself is still being developed, and that further work, of the type to be described below, should not only strengthen the prospecting powers of plate tectonics but also lead to other ways to usefully apply our new understanding of how the earth works.

At its present state of development, the plate tectonics concept is more effective in explaining the history of the ocean floors than of the continental masses, events at plate margins than at plate interiors, and lateral movements than vertical. It is a descriptive theory and offers few clues to the forces that incessantly change the face of the earth. We do not know what drives the plates; whether the genesis and destruction of plates is the result of push at the oceanic ridges or pull at the subducting trenches, or some combination of both. The formation of the Rockies, the Brooks Range in Alaska, or the Hawaiian Island chain is not obviously related to plate tectonics. In many cases, there is no apparent relationship between volcanic activity and the geometry and movement of the lithospheric plates.

As pointed out by the 1973 NRC report on the U.S. program for the Geodynamics Project,[†] "there are geodynamic phenomena that appear to be inconsistent with the plate tectonics model, and there are other phenomena that are apparently unrelated to it. This suggests that plate tectonics may represent only a partial model of the geodynamic process."

The Geodynamics Project, now under way, should reduce these inconsistencies and uncertainties, sharpen other geodynamic models, and generate new ones. The Geodynamics Project is

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[*] Ibid., p. 18.

[†] National Research Council. 1973. U.S. Program for the Geodynamics Project: Scope and Objectives. National Academy of Sciences, Washington, D.C., p. 8.

> an international program of research on the dynamics and dynamic history of the earth with emphasis on phenomena that affect surface or near-surface processes and structure. This includes investigations related to movements and deformation (past and present) of the lithosphere, relevant properties of the earth's interior, and especially any evidence for motions at depth.*

The U.S. Geodynamics Committee, organized under the auspices of the Geophysics Research Board of AMPS, in collaboration with other organizations, identified initial priorities associated with the following activities †:

Fine structure of the crust and upper mantle
Mid-Atlantic Ridge
Internal processes and properties
Chemical differentiation of magmas
Geodynamic models
Drilling for scientific purposes
Magnetic problems
Plate margins
Plate interiors
Geodynamic syntheses

The U.S. program for the Geodynamics Project uses the plate tectonics concept as a touchstone. These priorities are intended to detail various parts of the plate tectonics model, as is the case in the French–American exploration of the rift valley in the Mid-Atlantic Ridge, which is the first integrated study of a spreading plate region. Other parts of the program will concentrate on geodynamic processes not obviously involved in plate tectonics, such as the study of the chemical differentiation of magma, which is related to the formation of ore deposits. There's not enough space to describe all of the projects, but a brief elaboration of a few should give the flavor.

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* Ibid., p. vii.
† Ibid., p. 36–52.

FINE STRUCTURE OF THE CRUST AND UPPER MANTLE

The Mohorovicic (Moho) boundary, or discontinuity, between the earth's crust and the upper mantle is well known. But there are probably other less easily detected boundaries. Mapping them would improve the analysis of data on crustal structure and help decode the evolutionary history of the crust.

An effort is now under way to test whether seismic reflection techniques used by oil companies to locate likely petroleum-bearing formations can be applied to an analysis of the deeper part of the continental crust and perhaps even to the upper mantle.

These exploration techniques rely on "echoes" from surface shocks—explosives or truck-mounted vibrators. In oil company work, the recordings cover 6 seconds or less, adequate to allow two-way travel of waves penetrating somewhat deeper than the 9 km or so of sedimentary rock where oil has been found. Longer recordings should include reflections from deeper structures in basement rock forming the continental block. The feasibility of extending this reflective technique to obtain interpretable data from greater depths was tested in 1975 in two localities—Hardeman County in north central Texas and the Rio Grande rift area of central New Mexico—by a group called COCORP (Consortium for Continental Reflection Profiling). The particular seismic profiling technique used was VIBROSEIS (a trademark of the Continental Oil Company), and it produced diffraction and reflection waves from both crust and upper mantle. Two-way travel times of 14 seconds were recorded for some reflected waves, indicating depths of 45 to 50 km. The technique is still being explored, but if it repeats its early success, it will be a powerful tool in delineating the structure of basement rock and helping us understand past events in the interiors and on the margins of plates.

CONTINENTAL DRILLING

However rich the information one can gather with surface measurements, one would still like to have actual material from the crust and upper mantle in order to modify and amplify the geophysical information and to enable the correlation of rock structure with measured properties. A drilling program to recover material from basement rock that forms the continental platform has been proposed.* It recommends extensive drilling of fairly shallow holes (30 to 300 meters) and more selective drilling of deeper holes (300–9,000 meters). At least five major scientific problems of two types can be attacked in this way:

- Active processes now occurring in the crust.

1. The mechanism of faulting and earthquakes; e.g., drilling at varying depths of the San Andreas Fault would provide information on the character of the rock above and below the usual epicenters for quakes in this region.
2. Hydrothermal and active magma chambers; e.g., a study of hydrothermal water circulating around a magma chamber would aid in prospecting for geothermal deposits and in understanding the mechanism of mineral formation.

- State and structure of the continental crust.

3. Heat flow and thermal structure of the crust; this would aid in understanding the forces driving tectonic plates.
4. State of ambient stress in the North American plate; again, these data would help filter various ideas about the mechanisms that drive the plates.
5. Extent, regional structure, and evolution of the crystalline continental crust; the crystalline rocks that form the continental platform contain in their structure the evolutionary history of the North American plate and thus offer a view into the history of the plate and also information to guide future mineral exploration.

PLATE INTERIORS

The plate tectonics model forces a somewhat parochial view since it focuses attention on the plate margins. However, there is plenty of action within the plate interiors, as evidenced by the several major earthquakes that occurred in the eastern part of the United States in the nineteenth century, as well as by geodetic measurements indicating short-term vertical displacements of rock within the plate comparable in rate to the plate's horizontal movements. Whether plate tectonics has something to say

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* E. M. Shoemaker (ed.). 1975. Continental Drilling. (Report on the Workshop on Continental Drilling.) Carnegie Institution of Washington, Washington, D.C., 56 pps.

about these interior activities or whether alternative theories are needed to explain the facts is still uncertain. However, as an approach to some sort of explanation for what happens in the interior of plates, a synoptic synthesis of available geodynamics data is needed. For this reason, the Working Group on Plate Interiors of the U.S. Geodynamics Committee has proposed a traverse from the upper Michigan peninsula to the Atlantic Shelf off Cape Hatteras. The program will try to gather all pertinent and reliable geodynamic data available along the path of this traverse, including topography, depth to basement rock, thickness and attitude of suprabasement sediments, seismicity, crustal fine structure, heat flow within the crust, and so on.

PLATE MARGINS

While, by definition, the plate margins are extremely active areas, we have few fine details, particularly for different regions and different geological settings. We would like to know, for example, the different stresses or pressures on rock in different regions. We would like to search for the boundaries of smaller plates, now that the boundaries of the larger plates are fairly well defined. We would like to have the sort of data that might answer the earlier question of whether the plates move because they are pulled or because they are pushed.

Some of these questions may be answered by studying ancient or inactive plate boundaries, which have been relatively neglected compared to active plate boundaries. The U.S. program for the Geodynamics Project includes emphasis on the need for models of presumed ancient boundaries. As a first step, a series of cross sections—including precise determination of the timing of geologic events—is being undertaken across a dozen compressive plate boundary complexes (mostly ancient) in various parts of the United States—the Appalachians, the Sierra Nevada, the Klamath Mountains in Washington and Oregon, the Ouachita–Marathon region, and possibly the Rockies.

INTERNAL PROCESSES AND PROPERTIES

Ultimately, any ideas on the mechanisms of plate tectonics will be constrained not only by what happens at the surface but also by the physical nature of the materials in the lithosphere. The flow of heat through the crust, temperature and pressure profiles, the conditions under which rock structure changes, the sizes of pores within the rock, the nature and saturation of pore fluids, the velocity of sound through different rocks and at different depths—these and other data are needed if we want to understand the forces that shape the surface of the earth.

We can obtain some of the data from exposed crustal and upper mantle rock. The drilling program, if implemented, will reinforce those efforts. However, these *in situ* studies will always be limited to about 10 kilometers, well above the depths where geodynamic events related to tectonic processes occur. What is most exciting is that pressure and temperature techniques are now being developed that will subject rocks in the laboratory to geological conditions of pressure and temperature equivalent to those at depths of 600 to 700 kilometers. Newly designed diamond cells and laser heating techniques are among the tools used to attain those pressures and temperatures, while new diagnostic techniques, such as laser holography, enable the measurement of the properties of rock put under these stresses. Thus, rock strain or stress, sound velocities, and phase changes can in part be measured under conditions approximating those occurring not only in the upper crust but also deep within the mantle.

Along with these new techniques, we are becoming increasingly adept at synthesizing silicate and oxide crystals of minerals that are important constituents of the crust and upper mantle. Techniques for making some are already known; special efforts are under way to develop techniques for others.

These and other parts of the U.S. program for the Geodynamics Project form a carefully designed effort to capitalize on the revolution in the earth sciences in the 1960s. They seem certain to help our understanding of geodynamics, especially of near-surface phenomena that are so important to mankind. One may guess that new and perhaps even dramatic ideas will flow out of the planned geodynamic reconnaissance, just as the plate tectonics concept emerged from efforts to map the topography of the earth, the magnetic fields and their reversals, and the seismicity of the ocean basins in the 1960s.

NORRIS E. BRADBURY

9

Study Projects

FIRST GARP GLOBAL EXPERIMENT

Beginning in 1978, the earth's atmosphere and oceans will be observed with unprecedented completeness and detail in a mammoth international effort called the First GARP Global Experiment (FGGE). The experiment bridges the two goals of the Global Atmospheric Research Program (GARP): first, an increase in reliable weather prediction from about 2 days to 2 weeks and, second, an improvement in our understanding of climate —what forms it and what changes it. GARP has attacked these goals in two related ways: by the design and computational testing of models of atmospheric behavior and by actual observation of the atmosphere to help design these models and evaluate their validity.

Achievement of GARP's two objectives would undoubtedly realize many practical benefits, although their magnitude can only be guessed. Certainly, knowledge of what the weather will be a fortnight ahead would optimize agricultural operations (seeding, harvesting, and so on), construction scheduling, routing of ships and other transports, and advance scheduling of peaking power by utilities. A sounder comprehension of the elements of climate and what changes it should aid in the evaluation of the effects of man's presence and waste products on climate, the randomness of climatic change, and proposals for deliberately modifying climate.

FGGE, as described by a 1975 NRC report, *Understanding Climatic Change,* is "primarily an attempt to collect definitive global data sets for use in the improvement of weather prediction by numerical atmospheric models." Secondarily, it is an important part of the climate portion of the GARP. Much of the data will come from the World Weather Watch (www), by which the World Meteorological Organization coordinates the collection and dissemination of routine meteorological observations to the world's operational weather services. About 6,000 surface stations, 700 upper-air radiosonde stations, 7,000 ships, and operational satellites of the United States and the Soviet Union will contribute critical data. While broad, this data network has gaps. The poles, oceans, tropics, and the entire southern hemisphere are poorly observed. In an effort to fill these gaps, the nations of the world are readying a number of observing systems that will be deployed during all or part of the FGGE period. Five geosynchronous satellites launched by the United States, Japan, the European Space Agency, and the Soviet Union will be more or less evenly spaced over the equator. These will provide frequent visual and infrared images of cloud patterns whose displacements will indicate winds at various levels in the atmosphere. These observations will be particularly valuable over the tropical oceans.

Further data over the oceans, together with information on earth surface characteristics, will be provided by polar orbiting satellites of the United States and the Soviet Union. Their observations of infrared and microwave radiation emitted by the earth and atmosphere will yield temperature profiles from which the mass distribution of the atmosphere may be determined.

In the southern hemisphere, where routine observations are scarce, plans are to deploy 300 drifting buoys in the 20°S to 65°S latitude belt. Their observations of pressure, temperature, and oceanographic variables will be collected by satellite. Present indications are that Canada will assume the lead role in developing these buoys and providing for their delivery. Aloft, several hundred balloons floating in the lower stratosphere will provide wind, temperature, and pressure data. This system will apparently be provided by a French–Iranian partnership building on

France's extensive experience in balloon systems and satellite data collection.

Numerical experiments indicate that the tropics must be observed in great detail if the needs of atmospheric models are to be satisfied. Because the fields of mass and motion are but weakly coupled in these latitudes, a dense network of wind observations is needed to define the state of the atmosphere. Thus, the principal U.S. contribution of a Tropical Wind System is particularly significant.

This windfinding system employs long-range aircraft to release dropsondes in the 10°N to 10°S latitude belt. Each dropsonde carries meteorological sensors and receives signals from the Omega navigation system. These are relayed to the launch aircraft where they are processed and recorded. Changes in dropsonde position, determined from Omega signals, are used to compute winds. Approximately 117 daily drops will be made from base stations circling the equator.

Existing World Meteorological Centers will be used to the greatest possible extent in transmitting and processing the large mass of data. Global data sets produced with a 24-hour delay will be used for extended-range forecasts. More complete sets, utilizing data obtained too late for operational use, will be produced through follow-up data collection.

The timing of this ambitious program is now quite firmly locked to the launch schedules of key satellite systems. Data collection will start in January 1978, and by September 1978 all basic systems are expected to be operating. The observational phase of the experiment will be declared complete when a full year's data have been obtained.

The more exotic and expensive observing systems like the windfinding dropsondes and the southern hemisphere systems cannot feasibly be operated at full capacity throughout this entire period. Hence, two Special Observing Periods are scheduled for January–February and May–June of 1979. These are timed to coincide with the most vigorous part of the northern hemisphere winter and the development of the Indian monsoon.

The observational network of FGGE will also provide opportunities for smaller-scale investigations related to the goals of GARP. In the polar regions, POLEX programs of meteorological, oceanographic, and glaciological studies are planned. These will not only take advantage of the FGGE system but will also contribute observations to the FGGE data base. On a larger scale, a monsoon experiment (MONEX) is being planned to investigate not only the seasonal rains so vital to southern Asia but also the interactions between the global circulation and the annual cycle of heating over the Eurasian and African continents.

FGGE and its components are not, however, all of GARP. Other programs have been designed to mesh with them to advance our understanding and improve our ability to model the atmosphere. In the summer of 1974, for example, the GARP Atlantic Tropical Experiment (GATE) was conducted to gather data on the workings of the tropical atmosphere. This effort, in which dozens of aircraft and ships and thousands of scientific workers from many nations participated, has been termed the largest international scientific undertaking ever conducted. The data collected by this Dakar-based armada are now being processed and an international army of scientists is beginning programs of research that will span many years.

Under Japanese leadership, another international force carried out two month-long observing programs near Okinawa in the spring of 1974 and 1975. This Air-Mass Transformation Experiment investigated the interactions between ocean and atmosphere as cold air from the Asian continent flowed over the warm Kuroshio Current. The program was highly successful, and its results will be the subject of a series of study conferences planned for the years ahead.

Other international GARP subprograms and national efforts form part of the GARP scheme. The Soviet Union, for example, conducted CAENEX (Complete Atmospheric Energetics Experiment) programs in 1970–1972, and the United Kingdom plans to continue its air–sea interaction studies, termed JASIN.

The International Council of Scientific Unions (page 188) and the World Meteorological Organization have supported the GARP Joint Organizing Committee (JOC), a select group of scientists from many countries who define the scientific goals of the program and monitor its development. They are supported by a Geneva-based planning staff that doubles as the GARP Activities Office of the WMO. The actual contributions of governments to the programs are coordinated by organs of the WMO, while other international scientific bodies such as SCOR and COSPAR offer technical guidance within their fields of expertise.

The U.S. Committee for the GARP provides scientific guidance for American participation with the aid of panels and *ad hoc* groups concerned with GATE, MONEX, FGGE, POLEX, and climate research. Where appropriate, its advisory groups are formed jointly with other NRC activities, such as the Committee on Polar Research and the Ocean Science Board.

While GARP's observational programs are its most visible manifestations, its primary goal is to acquire knowledge, not merely data. Thus, research based on the information obtained by GARP field programs will extend for many years into the future. For example, the GATE Advisory Panel has established a group of coordinators with responsibility and commensurate funding to organize research based on the unique GATE data sets. For FGGE, a series of workshops is now being developed to elicit ideas for research in the early years of the next decade.

The first objective of GARP was to understand and predict weather. Its second and equally important goal was to understand the processes determining climate. As the programs addressing the first objective have taken shape, the attention of planners has moved to the problem of climate. A panel of the U.S. Committee devoted 2 years' effort to the scientific problems, and its report served as a valuable input to an international conference in the summer of 1974. At its tenth meeting in Budapest, the Joint Organizing Committee defined a GARP Climate Dynamics Subprogram on the basis of these studies. The program will build toward a Climate Dynamics Decade in the 1980s during which global observations, research, and modeling would be directed toward understanding the seasonal, annual, and decadal variations of world climate.

Thus, GARP—although more than a decade old—still looks forward to its greatest challenges: the observation of our planet's fluid envelope as a unified whole and the understanding of its long-term changes so vital to mankind's future.

U.S. Committee for the Global Atmospheric Research Program, Assembly of Mathematical and Physical Sciences. Chairman, Richard J. Reed of the University of Washington; Executive Scientist, J. Michael Hall; Executive Secretary, John R. Sievers.

EVALUATION OF THE NATIONAL CRIME SURVEYS

That crime statistics based on what is known to the police may be inadequate and misleading is not a new fact. Yet they continue to be used, partly because until recently, no other national crime data were available.

Since 1972, however, an effort has been made to discern the incidence and nature of certain crimes—rape, robbery, assault, theft, and burglary—through the National Crime Surveys, sponsored by the Law Enforcement Assistance Administration of the Department of Justice and conducted by the Bureau of the Census of the U.S. Department of Commerce. The endeavor consists of local surveys that have been completed in 26 major cities, paralleled by a continuing national survey of 60,000 households and 15,000 businesses.

In the national survey, the essential technique is repetitive visits every 6 months to the households and businesses by field investigators who ask a number of questions, for example:

> "During the last 6 months did anyone break into or somehow illegally get into your home, garage, or another building on your property?"
>
> "Did anything happen to you during the last 6 months which you thought was a crime, but did *not* report to the police?"

The Justice effort is a landmark in the gathering of crime statistics, in that it asks not what was reported but what actually *happened*. It is also a landmark in the social indicator movement—the measurement of societal state and change.

The effort is complex and expensive. Its annual budget is over $10 million, and there are methodological difficulties endemic to a retrospective study as large and novel as the Crime Surveys. In an effort to reduce those difficulties, the NRC Committee on National Statistics was asked in 1974 to evaluate the National Crime Surveys in two principal ways:

- Given a definition of objectives, how good is the statistical methodology—how complete, how accurate and reliable, how perceptive the analysis, how careful its dissemination? What questions can and cannot be answered by this technique?

- How useful are the results? Can the Crime Surveys improve our understanding of crime and aid in assessing its impact on society? What are the alternatives?

A 10-member evaluation panel was formed that included people knowledgeable in sociology, statistics, law enforcement, political science, law, and economics.

The first emphasis was on the objectives and methods of the surveys. The panel has been concerned, for example, that there is insufficient analytical staffing to interpret the data gathered by field interviewers. It has also attempted to interpret the effects of various types of "errors." For instance, what is the effect of "telescoping"—a victim mentally distorting the time elapsed between an incident and a report to the interviewer? The NRC evaluation panel has examined various efforts to measure the magnitude of telescoping and its effects on data reliability.

There is also the predictable fact that a victim simply will not always tell the interviewer about a crime. One way to gauge that effect is through a "reverse record check" in which a *known* victim is interviewed and his answers compared to the record. Although this method is a valuable research tool, the evaluation panel cautioned against the built-in biases of these checks, e.g., that *known* victims may not be representative of *all* victims. The panel also pointed out that

> it seems likely that incidents which had been reported to the police would be more likely to be recalled and mentioned to survey interviewers, partly because they are more likely to be (both objectively and subjectively) more serious, and partly because of the fact of having called the police, given details of the incident . . . might make the event more salient to the survey respondent.

An issue related to the reliability of victims' responses is that of "stranger" crime. The question is a simple one: Are you more likely to be victimized by a stranger or by someone you know? Advance survey reports indicate that in violent crimes, the criminal is more likely to be a stranger to the victim. This seems to contradict the known and frequently verified fact that, in most murders, the victim and the attacker knew each other.

A central issue, in the NRC's review, was the reliability of the interview technique itself. Pretests—the reverse record checks mentioned above—seemed to indicate that most victims would volunteer information about crimes to interviewers. The evaluation panel examined this conclusion and in a 1975 quarterly report pointed out that

> underreporting of assaults in the pretests was about 25 percent in the case of "stranger" crimes and about 80 percent in the case of violent acts committed among family members. It seems clear that if this form of bias has persisted in the national and city surveys done to date, it would badly distort the reporting of violent crime which actually obtains and grossly exaggerate the risk of those "stranger crimes" which the public fears most.

Besides data collection procedures, the panel has thought about who will use the information and for what. It strongly recommended that the data be catalogued so that it can be merged with information on neighborhoods—median income, population density, family size, ethnicity—available from 1970 census tracts. Without geographic information of this sort, the panel commented in a 1975 report,

> one cannot ask, for example, "Is there a difference in victimization rates of elderly persons who reside in predominantly young neighborhoods as compared with elderly persons who reside in senior citizen neighborhoods?" Or "Are victimization rates higher or lower in racially integrated neighborhoods than in racially segregated ones?" Or "Are people more or less likely to be victimized in their own homes if the population density in their neighborhoods is high?"

Such information is of no small import in the judgments we make on the state of society and our personal well-being. As Albert Biderman, of the Bureau of Social Science Research Inc. and a member of the Panel for the Evaluation of Crime Surveys, has written,

> we tend to regard the incidence of crime as probably the most critical manifestation of the failure of social organization. Crime involves a rejection of the moral code of the society. Various popular theories contend that an increased incidence of crime indicated the failure of society to function properly; a decreased incidence, a more effective society.

Panel for the Evaluation of Crime Surveys, Committee on National Statistics, Assembly of Mathematical and Physical Sciences. Panel Chairman, Conrad F. Taeuber of Georgetown University; Staff Director, Bettye K. Penick.

ATMOSPHERIC CHEMISTRY: CHLOROFLUOROMETHANES IN THE STRATOSPHERE

The issue of chlorofluoromethanes (CFMs) and their putative erosion of stratospheric ozone is resolvable for discussion's sake into several questions: Is the basic contention scientifically reasonable and sufficiently supported by available data? Are there "escape routes" that might mitigate or block the attack on ozone by chlorine released from CFMs? And, assuming the first two questions—within the range of uncertainties—are respectively answered yes and no, how urgent is the problem? By how much is the ozone layer reduced with time, what are the likely consequences of such reductions, and what are the follow-on implications for regulating the release of CFMs to the atmosphere?

THE ISSUE

There is little argument with the fundamental tenets: CFMs do accumulate in the troposphere (they have been measured); apparently, a significant proportion does enter the stratosphere (again supported by several recent measurements); CFM bonds (as measured in the laboratory) can be ruptured by ultraviolet radiation in the middle stratosphere—some 20 to 50 kilometers (12 to 30 miles) overhead; and, finally, once CFMs are photolytically dissociated, they do release chlorine atoms that (at least in the laboratory) catalyze a two-step chemical reaction whose net effect is the destruction of two odd oxygen molecules, atomic oxygen (O) and ozone (O_3). A chlorine atom is also regenerated, which, until removed from the stratosphere, can catalytically destroy thousands of ozone molecules.

ESCAPE ROUTES

If that basic scenario is taken as valid, the next question is whether the scenario is altered by events in the troposphere or the stratosphere. The fact that *measured* amounts of CFMs in the troposphere are roughly equal to the summed production to date is almost *prima facie* evidence that

CFMS remain in the troposphere for years and are not removed very rapidly, chemically or physically.

Once released by stratospheric photolysis, chlorine can, aside from ozone, react with any number of hydrogen-containing materials present in the atmosphere—methane (CH_4), hydrogen (H_2), hydrogen peroxide (H_2O_2), or hydroperoxyl radicals (HO_2)—to form hydrochloric acid (HCl), which, upon drifting downward, is eventually washed out by tropospheric rains.

But these reactions are apparently too slow to compete effectively with the attack of chlorine on ozone. As measured in the laboratory, the reaction of chlorine with ozone is 1,000 times more probable than its reaction with various hydrogenous molecules. Moreover, even if hydrochloric acid is formed, chlorine can be regenerated by subsequent reaction of HCl with hydroxyl radicals (OH). The formation of HCl is faster (several hours) than its dissolution by hydroxyl (a few days), with consequent reappearance of chlorine and start of another ozone-depleting chain.

The rate of the reaction of hydrochloric acid with hydroxyl depends on the concentration of the latter, and that in turn depends on the rate of reaction of OH with HO_2. That $OH + HO_2$ reaction, effectively a scavenger of hydroxyl radicals, can slow the regeneration of chlorine from hydrochloric acid by OH and thereby reduce the rate of ozone destruction.

Measurement of the rate of reaction of OH with HO_2 was one of several research recommendations of the *Interim Report of the Panel on Atmospheric Chemistry*, issued in July 1975.* The purpose of that report was to

> focus attention on a number of important atmospheric and laboratory studies that will aid in assessing the extent to which chlorofluoromethanes and other anthropogenic halogen-containing compounds will affect the ozone layer in the stratosphere.†

Aside from informed judgments relying on what is known of chemistry and transport in the atmosphere, there is the possibility of the unsuspected: reactions occurring in the troposphere or stratosphere that

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* Interim Report of the Panel on Atmospheric Chemistry. National Academy of Sciences, Washington, D.C., 8 pp.

† Ibid., p. 2.

remove chlorine rapidly enough to put ozone reduction below the point of concern. Such a *deus ex machina* is difficult to rule out, since that requires the consideration of all possibilities, with the implicit possibility that a critical factor may be overlooked. An ideal test would be a precise materials balance—i.e., measurement of the concentration of relevant atmospheric constituents and comparison with what has been released into the atmosphere. Another way to search out possible *stratospheric* sinks for both CFMs and chlorine is to compare observational measurements at different altitudes—e.g., of chlorine and chlorine oxides—with predictions by different models. Observational and predicted results should deviate appreciably if important chlorine-removing reactions are not included in the models used to calculate the effects of CFMs on ozone levels.

Aside from these specific considerations—removal of chlorine as HCl or the possible existence of unknown sinks—there is the complexity of the stratosphere itself. It has little wind, few clouds, and is populated by a wide assortment of chemical species: ozone itself, at less than 1 part per million; oxygen (molecular, various excited atomic forms); nitrogen oxides; and free radicals and other unstable chemical species. There are also particles of varying size and composition adrift in the stratosphere, and their participation and role in reactions affecting ozone are still under study. In any case, precise descriptions of stratospheric events are very difficult. For example, as an NRC report, *Environmental Impact of Stratospheric Flight,** pointed out: "It requires seven chemical reactions to give a minimum statement of ozone chemistry. It requires 30 to 50 reactions to carry out a quantitative treatment of stratospheric chemistry. . . ."

The character of the ozone layer adds to the complexities. There are gross variations in ozone levels, both in time and in latitude. There are, for example, daily changes of 5 to 10 percent, depending on season; annual changes of 5 to 25 percent, depending on latitude; and, superimposed on these, longer, less regular changes in mean global concentrations possibly extending over a decade or two, with the trend in the sixties a rising one followed by a general reversal in the seventies. But the cyclical changes

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* National Research Council. 1975. Environmental Impact of Stratospheric Flight. National Academy of Sciences, Washington, D.C., p. 119.

in ozone levels are really tangential to the problem raised by the proposed intervention of CFMS in the stratospheric ozone cycle.

The issue here is direct interference with natural phenomena: a unique, averaged, unidirectional change in stratospheric ozone. A helpful analogy is another global condition that fluctuates daily, seasonally, and even centennially—temperature. There is reasonable evidence that a change in mean global temperature of 1 degree or less can have significant effects; differences in mean global temperatures between a full ice age and today's climate are 4 to 6°C.* While reasoning by analogy has its faults, the evidence of global temperature is a useful model for clarifying the significance of a systematic change in ozone levels induced by CFMS.

Our lag in understanding stratospheric processes is evidenced by the fact that only within the past 10 years has the role of nitrogen oxides as a sink for ozone become known and understood. However, considerable progress has been made in the past 3 years through the Climatic Impact Assessment Program (CIAP) of the U.S. Department of Transportation, created to study the effect of jet aircraft emissions on ozone concentrations in the stratosphere.

The CIAP results—as well as the various models of ozone reduction that have been prepared and, especially, more recent laboratory and observational measurements—will be used by the Panel on Atmospheric Chemistry in making a judgment, within the range of uncertainties, of the existence of chlorine sinks, major and minor, and their likely effects on the extent of ozone reduction.

WHAT TO DO

If the scientific inquiry and the measurements uphold the basic contention, if no compelling evidence for alternate chlorine removal processes in the troposphere or stratosphere are found, and if the predicted extent of ozone reduction is significant, then the issue becomes one of what to do.

Of course, there is a spectrum of choices available, premised on a gradual reduction in the manufacture and use of CFMS. But at what rate? With what timetable? For what uses?

The touchstone in responding to those questions is the extent of ozone reduction and the time scale in which it happens. This depends on several things, including the rate of CFM transport to the stratosphere (very slow and estimated at about 1 percent per year) and the fraction of CFMS injected into the troposphere that is removed before it reaches the stratosphere (now thought to be very small).

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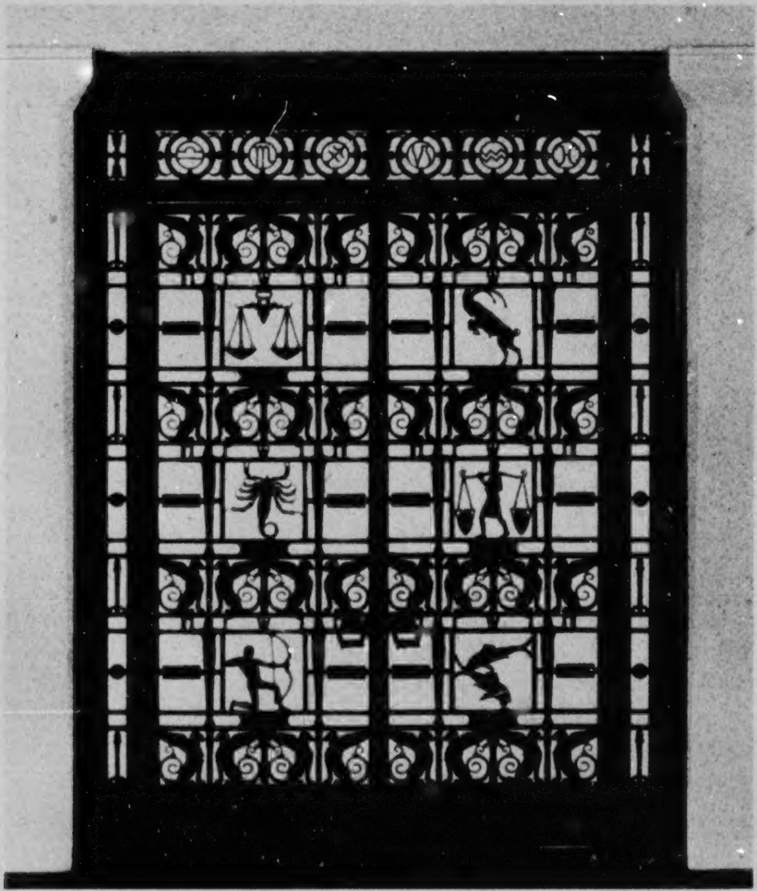
* Reid A. Bryson. A perspective on climatic change. Science 184:753.

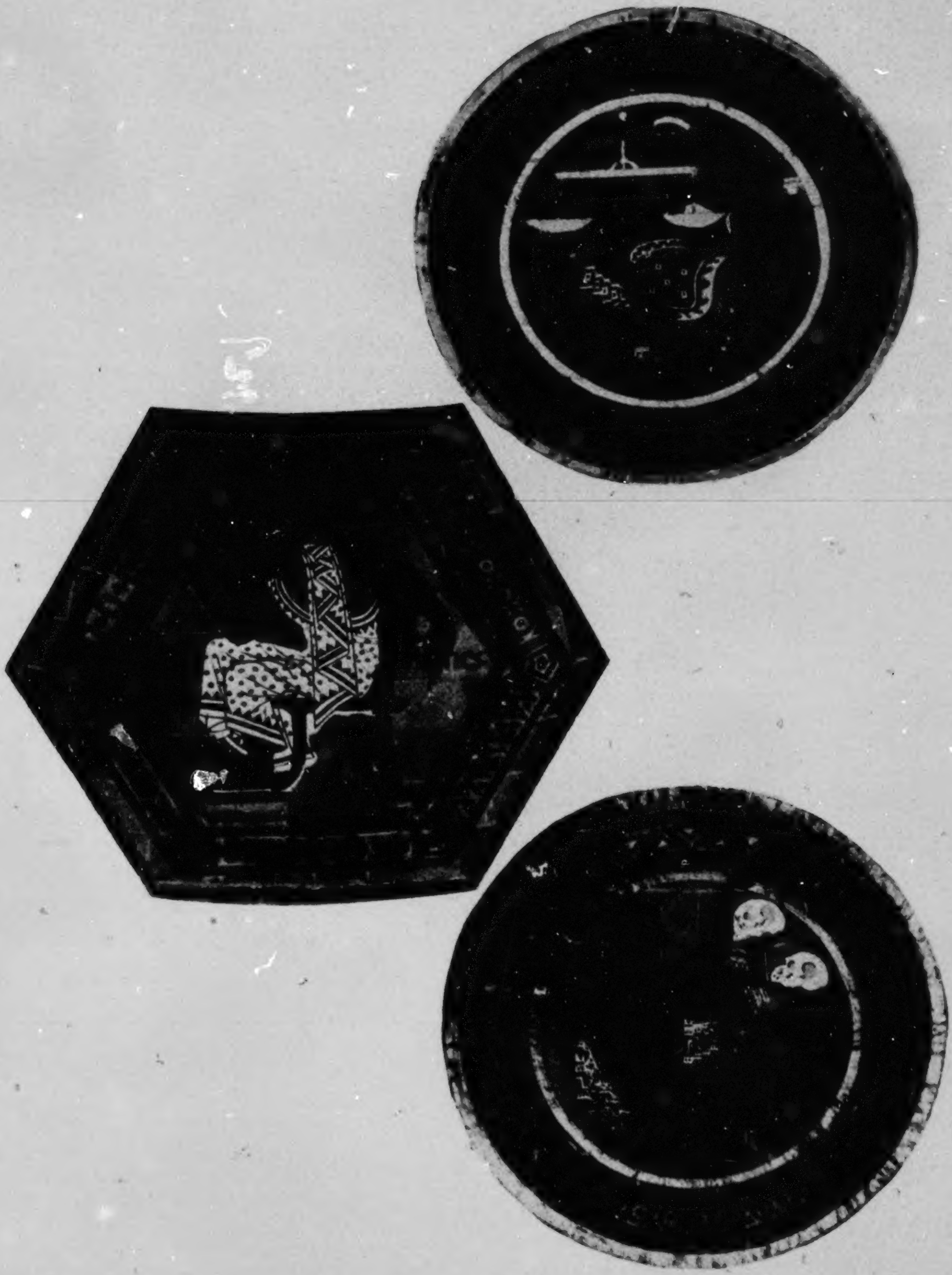
The slow atmospheric transport of CFMS and their extraordinary stability until they reach the middle stratosphere means that their effects on ozone levels can, in principle, continue into the next millennium, even if CFM use is stopped immediately. The question is thus what the extent of ozone reduction is over time, and what differences various timetables for reducing or ending CFM use will make in that level.

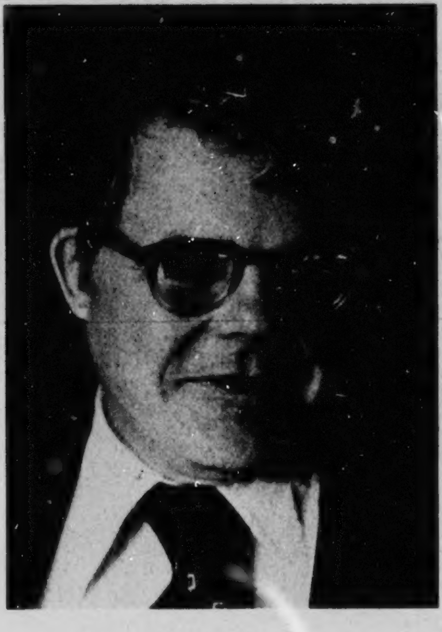
Several investigators have calculated the probable extent of ozone reduction with time, and, while they differ, the differences are not great, being at most a factor of two or three. The variations result from different assumptions about factors such as rate constants, photochemical behavior, and the rate of vertical transport into the stratosphere. Most of the transport calculations use an empirical model—eddy diffusion—that describes vertical transport but says nothing about horizontal circulation, simply assuming a very rapid horizontal spreading. The eddy diffusion model is derived from the measured transport of trace materials in the atmosphere. It has been used to estimate the rate of reaction of nitrogen oxides with ozone and atomic oxygen by incorporating into it the known chemical reactions of the stratosphere. The results have been reasonably good; however, three-dimensional models may eventually provide a more accurate treatment of the natural ozone cycle as well as of the CFM problem, although arguments can be made about how significant the improvements will be.

Quite obviously, as confirmed by the *Interim Report of the Panel on Atmospheric Chemistry*, there is a wide range of data and measurements that would be useful in shaping the Panel's judgments and recommendations. The Panel must determine the probable extent of ozone reduction and identify and estimate the sources and ranges of uncertainties in that determination. The Committee on the Impacts of Stratospheric Change will then devise recommendations based upon the Panel's results, including the various uncertainties. As Gordon MacDonald points out in his essay (pages 111–120), uncertainty, complexity, and the often antithetical demand of decision makers for firm yes/no judgments are virtually endemic to technological decision making. The situation in regard to the effect of chlorine from man-made sources on the ozone layer is no different; indeed, in the future this issue may be viewed as a model of how the technical community can render effective advice to policymakers on issues that ripple through society and affect a significant portion of our population.

Panel on Atmospheric Chemistry, Committee on the Impacts of Stratospheric Change, Assembly of Mathematical and Physical Sciences; Panel Chairman, H. S. Gutowsky of the University of Illinois at Urbana-Champaign; Staff Officer, Bruce N. Gregory.







GORDON J. F. MACDONALD
Chairman, Commission on Natural Resources

Commission on Natural Resources

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Science Advice on Environmental Regulations

Science advice in the middle of the 1970s differs in fundamental ways from what it was in the 1950s and 1960s, which some consider the golden era of science advice. The scientific issues then included ballistic missiles, nuclear weapons and nuclear energy, the space program, oceanography, and high-energy physics. All required very substantial government expenditures. The involved industries were for the most part not labor-intensive, rarely had large consumer markets, and were closely wedded to government action, since they and their employees were dependent on government contracts and subsidies. Scientists were often intensely involved in the formation of government policies affecting further development of the space program, oceanography, high-energy physics, and similar scientific and technical programs.

There was, in effect, a tightly knit community of common purpose: several major industries, the scientific and technical community, and various government agencies and congressional units—all interested in the furtherance of a variety of scientific and technical enterprises.

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But these programs—and the scientific advice that helped shape them—had little impact on the day-to-day activities of most Americans and actually directly affected relatively few. Even though billions of dollars were spent on highly visible technological enterprises, the only real involvement for most citizens was in the taxes they paid.

The regulatory environment of the 1970s changed that. The kind of cars we drive, the quality of our air and waters, the efficacy of our medicines and drugs, the kind of pesticides sprayed on crops, or the siting of an electric power plant are all affected in some way by regulations that have come into force in the past several years.

Our lives are now influenced directly by decisions of the regulatory agencies and by explicit regulations in legislation. Correspondingly, scientific advice impinges more directly and more meaningfully on the citizen in the mid-1970s than it did in the 1950s and 1960s.

Of course, regulatory legislation is not a new phenomenon, nor is associated scientific advice. The Food and Drug Act was passed in 1906; the Insecticide Act in 1910. The 1938 Food, Drug, and Cosmetics Act focused attention on the possible dangers to the public from the increasingly complex food industry. The Federal Insecticide, Fungicide, and Rodenticide Act of 1947 furthered interaction of science and regulation. But these laws were only a prelude to the crescendo of regulations to come from legislation passed in the late 1960s and early 1970s.

That the new regulatory setting would provide new difficulties for science advising was foretold in 1953 by the highly publicized case of the AD-X2 battery additive, which pitted scientific judgment and analysis against acceptance in the marketplace. A vendor of a chemical that was supposed to extend the life of storage batteries was challenged by government agencies, including the Federal Trade Commission. The FTC argued that the product had no merit, according to tests run at the National Bureau of Standards. The vendor provided testimonials from satisfied customers and was supported by the Secretary of Commerce and other political leaders in his opinion that customer acceptance was the real test of the value of a product. The regulatory agency felt that the law compelled it to use scientific evidence to protect the public by ensuring the quality and reliability of commercial products. But at that time political leaders felt that science should not be concerned with regulatory matters, and the vendor's position was upheld.

The complexities of today's regulatory decisions makes the AD-X2 case a model of simplicity. For instance, regulations on permissible auto emission levels affect a very substantial fraction of the nation's total economy and employment, and they have multiple international consequences involving not only balance of payments but overall international trade stability.

As the AD-X2 case warned us, implicitly technical questions are not always resolved on technical grounds. This remains true today. While scientific advice can be a useful guide to the decision maker in promulgating regulations affecting a good part of the population, it is not invariably the final arbiter.

NEW INSTITUTIONS AND NEW PROBLEMS IN ENVIRONMENTAL MANAGEMENT

To gain a better perspective on the regulatory arena in which science advice is now sought and given, it is helpful to examine briefly the genesis of environmental laws enacted within the decade.

Spurred by Rachel Carson's poignant *Silent Spring* and other works, political leaders in the congressional and executive branches in the 1960s intensified their interest in environmental problems. An example of this interest was a landmark study in 1965 by the President's Science Advisory Committee (PSAC), *Restoring the Quality of the Environment*. While clearly pointing to the need to increase the effectiveness of our regulatory base for environmental management, the study also strongly recommended a careful investigation of a "tax" system in which all polluters would be subject to "effluent charges in proportion to their contribution to pollution." While many of the recommendations of the PSAC study were acted upon, this particular one is still dormant, with the net effect that today's management of the environment has been given over to the regulators; i.e., rather than financial levies used to dampen pollution levels, the tack is a regulatory one that specifies allowable pollution levels—typically, ambient air quality standards are the basis for emission standards, which in turn are ultimately enforceable by the federal government and the federal courts.

A major element in setting the nation's environmental posture and in spurring analysis of programs and policies affecting the environment was the National Environmental Policy Act (NEPA), passed by Congress in 1969 and signed into law by President Nixon on January 1, 1970. Section 102(2)(C) of NEPA requires a comprehensive assessment of the wider and less easily measured environmental impacts of federal actions and policies.

NEPA was drafted as an administrative law in the sense that it requires federal agencies to "take into account" the wider and longer-term consequences of their actions. What was not clear from the legislative history or from NEPA itself was whether "to take into account" was a procedural or substantive requirement. Subsequent court rulings have left this question open.

The NEPA experience has encouraged analysts both inside and outside government to devise new techniques for project evaluation and to embark on a novel interdisciplinary decision-making process. However, many of the advantages of impact analysis, both real and potential, have not yet been assimilated in the decision-making process in the regulatory environment. Because of what is seen to be nonsubstantive consideration, such as congressional jurisdiction, the regulatory process itself has been exempted from the requirements set forth in section 102(2)(C) of NEPA. As a result, many opportunities for science advice exist in a different forum and format from those provided by NEPA.

Moving in sympathy with the forces that created NEPA were intense pressures to remedy the serious weaknesses in environmental management that were described in the PSAC report and by various public and private groups. Congressional leaders wanted reforms. A presidential commission headed by Roy Ash, citing dispersion of environmental regulation among a large number of federal agencies and subagencies, recommended the creation of a new agency with broad regulatory powers. In 1970, the Environmental Protection Agency (EPA) was created to take over the functions of a large number of small regulatory units in the government.

Shortly thereafter, the President signed into law the Clean Air Act Amendments of 1970. Thus, the fledgling agency was faced with the immediate task of creating and then enforcing a vast variety of regulations to control air pollution at the same time that it was organizing itself.

The coincidental creation of the EPA and the passage of the Clean Air Act Amendments influenced in a major way the development of the agency's regulatory philosophy. For example, the Clean Air Act required that primary air quality standards be set to fully protect the public health and that these standards contain an adequate margin of safety. In mandating these standards, the law assumed a threshold concentration for air pollutants below which there are no adverse health effects. But the wisdom of that assumption has been questioned. For example, it may be that susceptible people exhibit adverse health effects at concentrations below primary ambient air standards and even down to natural background levels.

However, the legislated requirement to fully protect the public health and the assumption of threshold concentrations at an early stage closed down other approaches to setting standards. For example, given more leeway, the agency could have adopted a cost–benefit–risk approach to standard setting. Rather than setting specific levels, a continuum of probable health risks for various segments of the population and control costs could have been established, and regulatory enforcement policy could have been set accordingly. An attempt could have been made to balance costs against health risks.

COST–BENEFIT–RISK ANALYSIS

Of course, while the cost–benefit–risk approach is attractive, it is often very difficult to apply in practice. Basically, it is much easier to calculate control costs than to assess in some quantitative way the benefits of avoiding health risks. But, in spite of the difficulties and the axiomatic point that one cannot measure environmental health solely in terms of dollars since one cannot price what is inherently priceless, cost–benefit–risk analysis does have the advantage of avoiding generalities. It focuses attention on dollar decisions. Since regulatory decisions can have vast economic consequences, this kind of quantitative analysis has the value of bringing together factors affecting costs and benefits in an organized way and thus facilitating debate on the adequacy or inadequacy of regulations.

Cost–benefit–risk analysis has the further value of making explicit fundamental underlying assumptions. Some have argued that where the health of the public is concerned, money is no object: "We must take every precaution—we cannot afford to compromise on the nation's health." However, costs are associated with every regulatory decision, and the most effe[illegible]e overall environmental program tries to put each dollar where it will add most to the total effectiveness. The emphasis should not be on cost, but on cost and effectiveness together.

But these sorts of cost–benefit–risk benefit considerations have been deemphasized by the evolution of the threshold concept, which, in turn, was essentially forced by the requirements of the Clean Air Act. Still, these considerations are—or should be—important in assessing the overall benefits of regulatory programs. For example, the control of emissions from automobiles will involve national expenditures measured in billions of dollars a year, though relatively little of this will be spent by the federal government. While these costs do not show up in the federal budget in the same way as sewage treatment plants do, they are just as real. In considering such expenditures, we should examine whether an additional billion dollars a year spent on controlling oxides of nitrogen from moving sources will be as effective in protecting human health as the same amount spent on controlling oxides of nitrogen from stationary sources. Or, would such an expenditure be more valuable to the overall health of the nation if it were employed in controlling the dispersion of toxic materials in the environment?

An examination of the marginal costs and effectiveness of various alternatives may be even more important in the legislative process than in the regulatory process, since regulations codified into law are difficult to change. For example, as mentioned above, the Clean Air Act requires that the EPA Administrator protect the health of the public with an adequate margin of safety, an implicit regulation. The same act also requires a 90 percent reduction in automobile emissions within a specified time, an explicit regulation.

These legislated timetables and goals have led to the promulgation of regulations to achieve short-term goals without concern for the long-term implications. The legislated strict automobile standards with short deadlines influenced if not actually forced the automobile industry to follow one particular technology, the catalytic converter, without paying sufficient attention to alternate technologies that perhaps offer greater promise for the long term. Short deadlines for municipalities in meeting sewage treatment requirements, as required by the Water Pollution Control Act Amendments of 1972, led to replications of past technology and little or no incentive to find better methods. Legislated time pressures have kept EPA from preparing a multiyear plan that weighs regulatory programs and their marginal costs against various technological options.

Planning for the future will require the careful analysis of the concept of threshold for health effects, the examination of technological options to achieve health standards, and the consideration of the long-term impacts of regulatory decisions. At a more fundamental level, the whole issue of whether regulation is the most appropriate tool to manage the environment should be seriously questioned. Other management tools, such as the use of effluent charges, need to be critically assessed. Otherwise, we may be frozen into an unmanageable system with an ever-growing regulatory bureaucracy.

ENVIRONMENTAL ANALYSIS

Whatever the process for making regulatory decisions affecting the environment, it should be done within as broad a context as possible. This is where scientific advice can perhaps be most helpful. In most cases, decisions involve elements that are part of a larger system, and good decisions recognize that fact. For example, regulatory decisions on effluent limitations of sulfur oxides from power plants should take into account the need to dispose of the solid wastes generated by stack gas scrubbers, the interaction of sulfur oxides with other components of the atmosphere, and the possibility of forming "secondary" pollutants whose adverse effects may be even greater than those of the sulfur oxides. The costs involved, the availability of the technology, and the implications for economic health of the affected region are also elements that require analysis. The electrical-power-generating plants emitting sulfur oxides are but one part of the larger, interrelated system. Rational regulatory decisions cannot be made without an understanding of that overall system.

The kind of environmental analysis required is not found in a single discipline. The analysis is not physics, engineering, mathematics, biology, medicine, economics, or political science; yet it will involve elements of all these disciplines. Environmental analysis requires much more a frame of mind than a specific body of knowledge. Like any good analyst, an environmental analyst must be a relentless inquirer, asking fundamental questions about the problem at hand.

Environmental analysis is not a panacea for problems of environmental management. Most environmental issues are highly complex, with variables of unknown or uncertain magnitude. No study can account for all the variables or quantify all the factors involved, but good environmental analysis can be an aid to judgment by clearly defining issues and alternatives, by indicating uncertainties in the data when such uncertainties exist, by clarifying underlying assumptions, and by further indicating the probable cost of hedging against major uncertainties.

A good analysis is characterized by openness, explicitness, objectivity, the use of empirical data, quantification, and a self-correcting character.

At the same time, it should be recognized that many of the underlying assumptions are either not rigorously verifiable or cannot be verified at all. Many of them involve value judgments to be made by policymakers as to what an uncertain future is likely to be or should be. The point of environmental analysis is not to give the answer but rather to show how the answer depends on various assumptions and judgments.

For example, the analysis of the costs and benefits of automobile pollution control strategies is not scientific in the same sense as physics or engineering. In important ways this kind of analysis draws upon the scientific method, using that term in its broadest sense; however, this fact does not make it scientific.

As in other fields of analysis, the assumptions drive the conclusions. There can be no doubt about the fact that there is not a single "right" set of assumptions, but only a variety of relevant assumptions, each more or less equally defensible. Ultimately, all environmental policies, and regulatory decisions, are made on the basis of judgment; there is no other way. The real issue is whether judgments have to be made in a fog of inaccurate data, unclear and undefined issues, conflicting personal opinions and hunches; or whether they can be made in the clearer atmosphere of relevant analysis and experience, accurate information, and well-defined issues.

Quantitative environmental analysis is possible even if there are uncertainties. And rather than concealing uncertainties, a good analysis will bring them out and clarify them. There is the obvious tendency to ignore important nonquantifiable factors, but this failing is less likely if a systematic approach is used in the analysis. The analysis must lay out clearly the assumptions, uncertainties, and calculations so that both the decision maker and the critics can see what was done and whether the analysis overemphasized quantitative factors. Good documentation of the analysis is essential if the regulator is to know which factors were used and which were neglected.

A good example of an analysis in which there were large uncertainties but that still clarified the basic issues was the 1974 NRC study, *The Costs and Benefits of Automobile Emission Control.*[*] Despite the lack of "hard" data, the study did arrive at a ballpark estimate of the damages resulting from automobile emissions and did provide guidance on the most economical strategy for controlling these emissions.

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[*] National Research Council. 1974. Air Quality and Automobile Emission Control. Vol. 4. The Costs and Benefits of Automobile Emission Control. U.S. Government Printing Office, Washington, D.C.

NEED FOR INDEPENDENT ANALYSIS

A sound environmental analysis also contains a recognition of the built-in institutional biases of various organizations that have a say in regulatory decisions. The Environmental Protection Agency has a legal responsibility to protect the environment and in so doing will have an institutional slant towards environmental protection. The Department of Commerce in commenting on regulations will have a different institutional slant, one protective of business and industry. The Treasury Department will be less concerned with the esthetic benefits of emission control but will emphasize international trade impacts. The Office of Management and Budget in its coordinating function will bring still a different view, with concern about the macroeconomic consequences of a particular regulation and the impact of that regulation on employment and overall economic well-being. Others will examine regulations from a political point of view. The agencies can call on outside consultants, but they are more likely to use those consultants who reflect the agencies' biases. In light of this, it is important that regulatory decision makers have independent analyses available to them.

Clearly, no group is completely free from bias, but freedom from biased institutional settings can help. This does not mean that the analysis proceeds without consulting with experts associated with various institutional points of view. But it does mean that the final analysis should be done in a setting as free from institutional biases as possible. The NRC—with its stringent selection of committees, its personnel, its bias forms, and its review procedures—provides an institutional base that is as independent and free from bias as is realistically possible.

Over the years, the NRC has presented to decision makers in the executive and congressional branches rigorous analyses pertinent to regulatory decisions. Some of the perils of that process are illustrated by the report of the May 1975 Conference on Air Quality and Automobile Emissions. This report, which drew on 4 years of efforts by various groups within the NRC, gave conclusions distasteful both to the regulator (EPA) and to the regulated industry. The analysis, which was open and documented, included many conflicting points, such as the state of development of the three-way catalyst, the saving associated with implementing a two-car strategy, and the health benefits of reduced carbon monoxide and hydrocarbon emissions.

Perhaps predictably but still surprisingly, since the report essentially reaffirmed judgments given in previous NRC studies, there was considerable criticism, principally from senior officials of the automobile industry. These criticisms were carefully examined and answered in a supplementary statement issued in late July 1975. None of the judgments in the original conference report were changed.

Finally, in considering the role of scientific advice and analysis in environmental decision making, it is well to recall that laws and regulations are not always drafted with sole concern for scientific facts and realities. These decisions are often highly political and, therefore, subject to intense political pressure. They can, in fact, affect a large fraction of the population, and as a result the decision maker is buffeted by the attention of the public media. These pressures often result in decisions that may appear to be intended to anticipate public reaction rather than flowing from a rational analysis. The public may not be well informed, and the anticipated reaction may or may not conform with the analysis provided by either independent or governmental groups. This may not appear to be the most rational approach, but it is a reality of the decision-making process.

CONCLUSION

It is commonly held that most environmental issues are too complex to be understood. The fact is that every effort must be made to understand them. This requires both analysis and judgment. Analysis by itself cannot answer many questions that may turn out to be the most important factors in any decision. There are also questions that cannot be answered by judgment and experience alone. A mix of judgment and analysis is essential if we are to have better regulatory decisions. The development of the methodologies and analyses of the kind described above can help restore public confidence in the wise use of the scientific method to deal with issues affecting a large fraction of the public.

GORDON J. F. MACDONALD

11

Study Projects

ANALYTICAL STUDIES FOR THE U.S. ENVIRONMENTAL PROTECTION AGENCY

The National Environmental Policy Act (NEPA) of 1969 declared it the policy of the federal government

> to use all practicable means and measures, including financial and technical assistance, in a manner calculated to foster and promote the general welfare, to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations of Americans.

NEPA's goals were seconded by a troop of environmental laws: the Clean Air Act Amendments of 1970, the Federal Water Pollution Control Act Amendments of 1972, the Noise Control Act of 1972, the Federal Environmental Pesticide Control Act of 1972, the Safe Drinking Water Act of 1973, and others. All these laws matched broad federal enforcement powers to stringent standards and deadlines. They effected remarkable changes for a society that historically had equated economic growth with progress: sharply reduced auto emissions, virtual banishment of DDT and other persistent pesticides, all the nation's waters swimmable by 1983, assessments in advance of the environmental impact of new governmental actions.

The laws were responses to a twentieth century "tragedy of the commons"—overuse of what is not priced. "Since we have not been able to assign private property rights to all the air and water," wrote Edwin Haefele, a political scientist, "we have owned them in common and cared for them least."

The new laws departed from the bottom-up mode of environmental decision making inherited from English common law. Instead, they enunciated national goals from which objectives and alternative ways to achieve them could be developed. The problems inherent in top-down or centralized decision making were often recognized, and opportunities for midcourse corrections of poorly chosen goals were provided. The legislative hearings were often lengthy and the laws complex and detailed in their mandates; the 1972 amendments to the Federal Water Pollution Control Act gestated for 3 years, cover 89 pages, and are exhaustive in detail.

But still none of the environmental laws passed in the 1970s said how to do it; the technological route was left the regulatory agency. What *is* the best practicable technology for controlling water effluents? Are catalytic converters the best way to achieve mandated auto emission levels within a specified time? What standards should be set for various industrial effluents to meet water quality standards? Which pesticides should be banned, and which should not? What are acceptable noise levels for new construction machinery? Are tall stacks a valid way to comply with the nation's wish for cleaner air? Are effluent standards the best approach in all cases, or might other incentives—such as effluent charges—be better under some circumstances?

The new laws gave to the Executive the power to make decisions that are inherently difficult, that invoke uncertainties, and that must rely on a well-reasoned ordering of scientific and technical information (which in any case is always incomplete and uncertain). The laws are pervasive and often have serious effects on national and regional economies, on the relationships of states to the federal government, on business planning and profits, and on the style of American life.

The new laws have had difficulties. Some regulatory decisions have, in retrospect, been unfortunate ones. Legislative language has at times seemed ambiguous in interpretation and unworkable in practice. Judicial review has in many cases—e.g., the cost effectiveness of sulfur oxide removal from stack gases, the adequacy of environmental impact statements, the health effects basis for limiting asbestos fiber discharges into Lake Superior—superseded the decision-making process, subjecting it to the limitations of the adversary process.

There *has* been substantial progress, albeit in scattered areas. There *are* measurable improvements in the quality of urban air, although in some urban areas primary health standards for air pollutants will not be met for many years. Secondary or biological treatment for waste water is now more common, although phosphate and nitrate nutrient levels are apparently increasing in many water systems.

So it is against a backdrop of both real progress and continuing controversy over whether future benefits justify present costs that the NRC has undertaken a series of analytical studies of regulatory decision making by the U.S. Environmental Protection Agency. Five million dollars was allocated for the effort by the Congress in the 1974 EPA Appropriations Act.

The essential purpose of the NRC studies is to analyze the way EPA makes decisions and suggest improvements, particularly in assuring that it makes optimal use of scientific and technical information, reaching carefully evaluated, interpreted value judgments, clearly distinguished from facts, and making them available to politically responsible officials in a timely manner and in a useful format. Given various ways of applying what we know—e.g., mathematical models for simulating the real world and predicting the effects of specific actions—what is the best we can do in carrying out the intent of the nation's environmental laws?

The Academy's effort to assist the EPA is composed of a great many pieces (Table 1). There is first an examination of the decision-making process itself: How has it worked in the past, as applied to specific situations—e.g., use of DDT against the tussock moth in the Northwest in 1974; fitting of regulatory options in the Clean Air Act to cadmium, vinyl chloride, and other chemicals; and regulation of automobile emissions? How might decisions be made within an "ideal EPA"? And how can they be better made in the real world without ignoring realities—information uncertainties, costs, social disruptions, energy supply, pressures from private interests, and the political effects?

Cost-benefit analysis in decision making will be explicitly examined

Table 1 Analytical Studies for the U.S. Environmental Protection Agency

Project	Committee Chairman	Staff Officer(s)
Steering Committee for Analytical Studies	R. M. Solow, Massachusetts Institute of Technology	C. R. Malone, R. F. Ehrhardt
Environmental Decision Making	J. P. Ruina, Massachusetts Institute of Technology	R. G. Kasper
Environmental Research Assessment	J. M. Neuhold, Utah State University	M. F. Uman, E. Groth
Review of Management of EPA's Research Activities (completed)	R. W. Berliner, Yale University	
Environmental Monitoring	J. W. Pratt, Harvard University	M. L. Straf, J. S. Hunter
Environmental Manpower	E. F. Gloyna, University of Texas, Austin	S. J. Ware, P. P. Nowers
Ocean Disposal (completed)	D. S. Gorsline, University of Southern California	R. H. Burroughs
Energy and the Environment	S. I. Auerbach, Oak Ridge National Laboratory	E. J. Salmon
Societal Consequences of Transportation Noise Abatement	W. J. Baumol, Princeton University and New York University	J. Singer
Use of Scientific and Technical Information in Pest Control Decision Making	W. G. Eden, Lawson Community College, Birmingham, Alabama	F. Clayton
Study of a Multimedia Approach to Municipal Sludge Management	Harvey O. Banks, Harvey O. Banks Consulting Engineer, Inc.	R. H. Burroughs

by the Committee on Environmental Decision Making. Cost–benefit analysis is an old technique, used by government to assess actions involving goods, services, or consequences for which the market has not set a price. An electrostatic precipitator or a secondary treatment plant has a market price, but a fractional reduction in particulate matter or a cleaner river does not; government must, in effect, do the pricing and make the choices for the market. Of course, cost–benefit analysis in its grossest form—do the extra or marginal costs outweigh the marginal benefits, or don't they?—is simple common sense (if the data exist). It is in the shadier areas, where it is difficult or impossible to evaluate the benefits or even to identify them, that the technique begins to run into trouble.

The heart of the issue, as explained by Robert Dorfman of Harvard University, a member of the Committee on Environmental Decision Making, "lies in deciding what benefits should be included and how they should be valued. The debate about benefit–cost analysis centers on the question of whether the social value of benefits can be estimated reliably enough to justify the trouble and effort involved in a benefit–cost computation." That will be one of the judgments of the Committee.

The fodder for benefit–costs analysis is information. The Committee on Environmental Monitoring (CEM) will consider how information is and should be gathered, in what form, using what sort of selection criteria, and by what paths it enters and moves through the decision-making process. As noted by the Council for Environmental Quality in its fifth annual report, there is "a critical need for accurate and timely information about environmental conditions and trends, in order that important decisions affecting environmental quality and natural resources can be made on the most informed basis possible. The key word here is information, not just data."

At first, considering the widely reported powers of analytical instrumentation, monitoring seems to be an issue where answers outnumber questions. But this conclusion ignores the capriciousness of nature. A measurement of sulfur oxide levels must factor in the local weather when the measurement was taken, the location of the instrument (e.g., how near a power plant or highway?), the time of day, and the height of the instrument—at ground level or rooftop. Sophisticated monitoring must also allow for the transformation of pollutants by atmospheric chemical reactions, some understood and others not.

Monitoring without sophistication not only adds to contention but also can so confuse regulators that they may not know what action to take nor what the effects will be if they do act.

A corollary to the need for intelligent gathering of data is the need to communicate it in a form that is usable to decision makers not sensitive to the nuances of analytical chemistry. The probabilistic nature of measurements should be made clear. The understandable wish to collate data and condense it into a few numbers or indices, or even to a single value, may lead to deception, if the origin of the numbers, and their qualifiers, is not made plain.

To monitor means to understand what to look for, and that means research. It means understanding the impact of chemical reactions on biological systems in rivers and lakes and the lesser known reactions in the atmosphere. It means being able to differentiate qualitatively and quantitatively between natural and man-made atmospheric components. These and other issues in research are being considered by the Committee on Environmental Research Assessment.

Particularly lacking are reliable indicators of the relationship between constant exposure to a low level of a specific chemical and the biological response. "Presently available data," comments a report of the Council on Environmental Quality,

> on such health effects involve many uncertainties. For the most part, these data do not enable the accurate identification of pollutant levels which constitute the "lower limits" for producing such effects. Rather, most such levels have been necessarily estimated, often somewhat crudely, and possibilities exist that some present ambient standards may be set too high. Secondary effects, including damage to property and vegetation, are even less well understood.

These NRC core studies on environmental decision making, monitoring, and research needs are supplemented by an analysis of environmental manpower needs. Singular in the methodological difficulties it poses (refer, for example, to the article in the human resources section on the study of biomedical and behavioral research personnel needs), this study will try to estimate future needs for people with various kinds of training at various levels of the environmental control process and then will suggest how such people can be recruited and trained.

There are (as indicated in Table 1), several studies of specific issues, each probing the many difficulties of environmental decision making. For example, the study on pesticides and regulatory decision making should, like a fine miniature, render in detail the trials of the larger world of environmental management. The governing statute is the Federal Environmental Pesticide Control Act of 1972 (FEPCA), which amended the Federal

Insecticide, Fungicide, and Rodenticide Act of 1947. FEPCA was intended to move the locus of decision making in pesticide regulation from the courts to the more appropriate arena of scientific and technical judgment. It has not quite worked out that way. The process of judicial review has pulled scientific evidence and judgments back into adversary proceedings. The committee will examine some of the difficulties that arose: How is scientific information used in the adversary context? How is it evaluated and validated in public hearings?

There are other issues. The effort will conclude in March 1977 when a report, synthesizing the findings of all the committees, will be issued by the steering committee for these studies, chaired by Professor Robert M. Solow of the Massachusetts Institute of Technology.

Steering Committee for Analytical Studies for the U.S. Environmental Protection Agency, Commission on Natural Resources. Chairman, Robert M. Solow, Massachusetts Institute of Technology; Executive Secretary, Charles R. Malone.

REDISTRIBUTION OF ACCESSORY ELEMENTS AND COMPOUNDS ASSOCIATED WITH MINERAL RESOURCES EXPLOITATION

Necessary to the sort of environmental analysis described by Gordon MacDonald in his essay is not only the availability of basic information, but also some assurance of its quality, scope, completeness, and timeliness. We are now painfully aware that we must assess in advance the environmental effects of our activities, most particularly when those activities are large in scale, involve the use of new technologies, and exploit new resources.

The study described in the title is an effort by the NRC Board on Mineral Resources to analyze what we do know and what we need to know in order to assess potential by-product production and environmental loading from future mineral exploitation.

The present study represents a continuation of concerns for auxiliary impacts associated with future mining operations as expressed in the 1975 NRC report on mineral resources and the environment *:

> • The situation where wastes associated with resource extraction were small enough to permit of easy disposal no longer obtains; many parts of the environment can no longer "dispose" of or "process" all the wastes they receive without detriment [p. 288].
> • Future trends in conventional mining will require resort to leaner ores, and ores in less accessible places. More material will have to be moved in order to realize the necessary levels of mineral production [p. 54].

The task of the study, as summarized in the proposal, will be to provide

> a review and assessment . . . on the adequacy of the chemical information base, the chemical nature of the new deposits, the kind and degree of accessory element and compound production and the consequent redistribution of various chemical species. The study would aim to provide an alert to potential problems of environmental loading and provide recommendations for program planning, research needs and alternative technological options.

The deposits to be looked at are present or future candidates for intensive exploitation. They include coal, uranium, and oil shale deposits, as well as new sources of iron and aluminum ores.

COAL

Sulfur in stack gases and acid wastes draining from abandoned coal mines are well-known examples of the "environmental loading" due to coal mining. Coal, because of its plant origins, is endowed with many elements, particularly metals. The concentrations vary, but local coal deposits may be quite rich in some of these "impurities," and, in fact, some lignitic coals are a possible source of uranium. While we have a reasonable general understanding of the chemistry of coal and its deposits, we lack the firm data on regional variations that will be needed both to plan the control of the untoward effects of coal mining and to plan for the recovery of useful by-products. The need is obviously imperative, since, according to current projections, coal production may well double by the year 2000, with much of that increase coming from strip mines in the West.

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* National Research Council. 1975. Mineral Resources and the Environment. National Academy of Sciences, Washington, D.C.

OIL SHALE

Oil shale is a marlstone containing a solid hydrocarbon from which oil can be recovered by simple heating. However, even for the richer oil shales, such as those of the Piceance Creek basin in Colorado, an enormous amount of rock must be dug out of the ground to recover economic quantities of shale: 1.5 tons of high-grade oil shale for a barrel of shale oil is an accepted figure. Moreover, a great deal of water is needed to process shale in a region that already has relatively little of it. The water may leach salt out of the spent shale, adding to the already serious salinity problems of the Colorado River. Whether, in fact, oil shale will be exploited to any significant degree is still problematical and will partly depend on the world price of petroleum and on our confidence that known and probable environmental problems can be dealt with. The sweeter side of oil shale mining is that there are valuable, perhaps economically recoverable, by-products, including aluminum and uranium.

URANIUM

Uranium oxides to fuel light-water nuclear reactors now come from sandstone deposits in Colorado, Utah, New Mexico, Wyoming, and South Dakota. These deposits, while scattered and localized, can be quite large. According to a report of the Committee on Mineral Resources and the Environment, they vary from "a few thousand to a few millions of tons, and in size from tens of feet to thousands of feet in length."[*] How extensive these deposits are and how much uranium can in fact be extracted from them are still being debated; of course, the cat among the pigeons in this debate is the breeder reactor, which, by converting the most common form of uranium into a fissionable material, can enormously multiply U.S. uranium supplies. However, beyond the sandstone deposits, the United States has other, albeit low-grade, uranium deposits. It is the latter that will be the principal concern of the study. A roster might include mica granites, lignitic coal, phosphate rocks, copper deposits, and the Chattanooga black shales of the Western Appalachians that reach across Tennessee, Alabama, Kentucky, and bordering states. The latter contain an enormous amount of uranium, but in low concentration; typically, the Chattanooga shales contain on the average less than 0.008 percent uranium, compared to 0.1 percent for \$15/pound U_3O_8.

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[*] National Research Council. 1975. Mineral Resources and the Environment. Supplementary Report: Reserves and Resources of Uranium in the United States. National Academy of Sciences, Washington, D.C.

IRON AND ALUMINUM

These metals are the most abundant in the earth's crust, and for the immediate future the United States has access to rich and plentiful ores of both—principally bauxite for aluminum and unleached, low-grade ores or taconites for iron. However, technology, rising resource prices, and the uncertainty of nondomestic sources of ores may make other ores economically appealing.

High-alumina clays and anorthosites are alternative aluminum resources. Pilot plants to extract high-alumina clays have been operated in the United States, while techniques for the economic extraction of anorthosites are being developed by the Soviet Union and France. The alumina clays now seem the better supplement to bauxite, since they are subject to the economies of scale through large-scale strip mining of alumina clay deposits in Arkansas and elsewhere.

CONCLUSION

In all these cases, the Committee will consider what sort of knowledge we have and what kind we will need in order to assess the effects of rearranging the elements and compounds associated with these ores. Reports on each resource will be issued periodically, starting with coal. The study itself is scheduled for completion in the fall of 1977.

Committee on Redistribution of Accessory Elements and Compounds Associated with Mineral Resources Exploitation, Commission on Natural Resources. Committee Chairman, Arnold J. Silverman of the University of Montana; Staff Officer, William R. Thurston.

HARVEY BROOKS
Chairman, Commission on Sociotechnical Systems

Commission on Sociotechnical Systems

12

Sociotechnical Systems: Central and Distributed Goals

In 1969, an NRC committee chaired by Daniel Alpert of the University of Illinois produced a report entitled *The Impact of Science and Technology on Regional Economic Development*. That report was one of the first to distinguish between "two major categories of national goals" for research and development: central national goals, typified by the space program, military research and development, and biomedical research on the major diseases; and distributed national goals, typified by the development of human resources, rebuilding of cities, and conservation of water resources. Programs in the second category were further characterized by problems that are largely local in nature, in the approach to their solutions, and in the consequences of these solutions.[1]

This categorization is a convenient one for analyzing current National Research Council activities; however, the categorization must be considered in terms much broader than research and development *per se*. Indeed, for distributed national goals, it is much more difficult to draw a sharp line between R&D and the rest of the process of innovation. Innovation in the realization of distributed national goals involves the interaction of many different levels of government and a complex network of private institutions, including planners, suppliers, and consumers, both as individuals and collectively. A "science and technology policy" for these distributed goals cannot focus solely on the R&D process but must look at the whole spectrum of public policies that influence the direction and rate of innovation in the delivery of services to the public in the various functional areas. These policies include the allocation of human, natural, and financial resources; regulation; subsidies; taxes; interpretation of antitrust laws; fiscal and monetary policies; patents; and the like. Each of these policy elements helps determine what research and development is actually undertaken in the private sector, as well as the ability and willingness of the system to assimilate the results.

The most important change in national science and technology policy that took place during the 1960s was the shift of emphasis from central to distributed goals in national priorities. The shift in focus and interest has in general exceeded the shift in actual R&D resources. The lion's share of federal funding still goes into R&D in space, defense, the cure of specific universal diseases such as cancer, and the development of new centralized energy supply technologies. But, using the current activities of the NRC as an example, one sees a much greater shift in emphasis toward distributed goals. Even within a single area such as biomedical research, the focus of interest has shifted significantly toward the study and improvement of the health care delivery system as a whole.

Of course, with a closer look, it is clear that a sharp distinction between central and distributed goals is never possible. For any given national goal there are both centralized and distributed aspects. In the words of the Alpert report:

> In addressing such distributed or regional problems as transportation, air pollution, waste disposal, control and prevention of crime, what is typically needed is a combination of centrally directed research broadly oriented to the problems, and locally directed R&D that views the problems in terms of specific local constraints.[2]

The federal agricultural research program, with its combination of central federal laboratories, state experiment stations, and local product-oriented laboratories, is often cited as the ideal pattern of such a blending of central and distributed research institutions,[3] although this pattern runs into the dangers of parochialism and capture by overspecialized interests.[4]

DISTRIBUTED GOALS IN THE NEW NRC

Whereas centralized goals are manageable from the center (as the name implies), distributed goals are much more difficult to manage in the classical hierarchical manner that has been relatively successful in, for example, the space program. Indeed, it may be argued that most recent efforts to foster innovation in the transportation and construction sectors through direct federal intervention in the research and development process have been less than successful, if not outright disastrous.[5] The failures come from a variety of causes, but most frequently from the inability of the federal R&D management process (including the contractor) to interface continuously and effectively with the clientele that the R&D is supposed to serve and with the institutions and social interests that participate in or are affected by the implementation of the R&D results in actual operating systems. Too often, federally supported R&D in the civilian technology area attempted to follow past successful management patterns in the space and defense areas. But in those cases the federal government itself is the ultimate client and user, and the technology in a sense enters a social and organizational vacuum with no existing technostructure and no network of organizational vested interests other than those engaged in the performance of the R&D itself.[6]

In the past, the structure and priorities of the NRC have partly reflected the orientation of federal R&D. To some extent the activities of the NRC have reflected a dual structure. The membership of the National Academy of Sciences and National Academy of Engineering and thus the central management of the NRC derived from that membership have focused largely on problems related to centralized R&D. But, at the same time, major operating elements of the NRC, concerned with distributed R&D in transportation, housing and building, agriculture, nutrition, and so on, have operated quite autonomously and have been of only peripheral interest to the membership of the Academies. The significance of the recent reorganization of NRC has been to bring distributed R&D—or, more accurately, the distributed innovation and planning process—much closer to center stage. Each of the new commissions and assemblies of the NRC has been trying in its own way to adapt to this new orientation. Because of the past lack of interest of the Academies, many of these distributed-goal activities have tended to operate in close collaboration with a client group of suppliers engaged in carrying out a certain social function in civilian technology; examples include state highway departments and highway builders; architects, builders, and urban planners; and the materials industries.

In these distributed R&D areas, the NRC is learning how to walk an indistinct line between purely technocratic central planning on the one hand and complete acceptance of the assumptions and technical habits of thought of an established supplier constituency on the other. The first alternative means writing reports for federal agencies, which usually get praise from scholars but go into the archives without much further attention. The second often involves suggested solutions for detailed technical problems of a short-range nature. Rarely is there an examination of the implications of present trends or of impacts on a broader population beyond traditional supplier and consumer constituencies. The Commission on Sociotechnical Systems (CSS), whose responsibility includes the areas of transportation, building, materials, and emergency planning, among others, has had to face this tightrope-walking dilemma with particular sensitivity, although this Commission is by no means unique in having to come to grips with the problems of distributed innovation.

TRANSPORTATION

Such problems are well illustrated by transportation. Transportation in the United States has developed as a congeries of separate systems based on particular modes or technologies. As new modes of transportation became technologically feasible, the federal government developed separate and often nearly autonomous agencies to deal with these modes and with their particular groups of suppliers. Thus we have a Federal Railway Administration, a Federal Highway Administration, a Federal Aviation Agency, an Urban Mass Transportation Administration, a Maritime Administration. The legislative directives to these agencies have been written at different times by different congressional committees in response to pressure from different political constituencies. These legislative mandates, and the associated systems of taxes, subsidies, regulatory policies, and relations with the private sector and state and local government, do not constitute a national transportation policy. Nor do they always relate sufficiently to the impact of transportation on people and institutions other than its clients and suppliers.

Recently we have superimposed on this collection of modal transportation policies a whole series of cross-cutting legislative mandates with respect to air quality standards, land use planning, environmental impact statements (including impact on the depletion of natural resources), energy conservation, and employment. The number of interests or constituencies that must be taken into account in transportation planning has grown explosively, and with it new sources of conflict, confusion, and uncertainty about the future.

The NRC has tried to respond to these developments in transportation, first by broadening the charter of its Highway Research Board to that of a Transportation Research Board (TRB) and more recently by trying to bring closer together the activities of the Maritime Transportation Research Board (MTRB) and of the TRB. For several years, both boards have been attempting to extend their concerns with socioeconomic and environmental issues, as opposed to strictly technical ones.

An increasing proportion of TRB activity is concerned with the transportation planning process, especially in relation to the socioeconomic impact of transportation. This is true both in the regular activities of TRB and in the National Cooperative Highway Research Program (NCHRP), which is administered by TRB. As an example, transportation planning in an urban setting usually begins with estimates of urban travel demand. Current procedures typically take as long as 3 years. This is no longer adequate because of the increased involvement of local officials and citizen groups in the planning process and because of requirements such as environmental impact statements, corridor hearings, and consideration of "no-build" options as prescribed under section 102 of the National Environmental Policy Act. Under such conditions, decision makers need a much quicker response from analytical efforts. Policy committees often demand that new alternatives be considered within a month between committee meetings or before public hearings.

The National Cooperative Highway Research Program has let a contract with the Metropolitan Washington Council of Governments (COG) to investigate ways of expediting the analytical process. COG's approach is first to identify the generic urban policy issues likely to arise in the public process and then to evaluate and redesign travel-estimating procedures so as to be more directly responsive to these issues. The idea is to devise a tested operational tool that is much better adapted to participatory transportation planning than are the classical techniques dating from a more technocratic age.

Another NCHRP project deals with the evaluation of the "no-build" option. Present assessment processes are set up to evaluate the impact of alternative highway or transportation routing, but when citizens ask why the facility should be built at all, planners are usually reduced to hand-waving about local employment or economic growth. There are no good analytic methods for evaluating the socioeconomic and environmental consequences of doing nothing.

Another project of NCHRP, closely related, is to improve the methodology of statewide and regional multimodal transportation planning in order to better accommodate new land-use policies and air quality and energy conservation requirements. The ultimate objective is to collect findings into a single volume that can serve as a guide to transportation planners.[7]

Reliable data closely related to transportation planning were the subject of a study released by the U.S. Department of Transportation in 1969.[8] It pointed to the great need for reliable transportation data for effective national transportation planning and estimated that the necessary data collection would take 5 years and cost $36 million, with an annual cost of $6.5 million for updating. According to William N. Carey, Executive Director of the TRB, a national transportation policy

> can be formulated only through the construction of and careful consideration of the output from a massive model of the overall system of transportation of people and goods. . . . We simply do not know where people are traveling and why, nor do we know what goods are being shipped and where, by what mode, at what cost, and during what time.

Only with the aid (though not the dictation) of such a model can rational choices be made

> among available alternatives such as improved highways, dedicated bus lanes on streets, rail transit, and new technology and among alternative strategies such as staggered work hours, rearrangement of urban patterns, congestion pricing, and the like. Such decisions are now influenced more by emotion and special-interest politics than by reason.

The planning of transportation involves too many conflicting interests and values to permit the hope of a completely rational process of decision making. The process is inherently political, because politics is about such conflicts. But models and data can help point out interrelations between issues and the consequences of alternatives. In many cases, they can show that what appeared to be a zero-sum game can be turned into a positive-sum game in which interests or values thought to be in conflict both benefit.

One type of data gathering, in which TRB is only peripherally involved, illustrates the kind of work that is necessary. In the past 20 years, most discussion of highway transportation has focused on the Interstate Highway System, which may be regarded as one of the "central national goals" of transportation policy. In fact, however, 22 percent of all road mileage in the United States is rural 2-lane highway, which accounts for 32 percent of all traffic (vehicle-miles) and 48 percent of all traffic fatalities. To improve this kind of highway, the Federal Highway Administration, the Transportation Systems Research Center in Cambridge, and the Maine Department of Transportation have cooperatively instrumented a 15-mile stretch of U.S. Route 2 in Maine. The instrumentation includes 37 portable vehicle detection stations, 406 fixed vehicle-sensing loops under the pavement, and 5 in-vehicle receiver-display units, all connected to a central data processor. The NCHRP conducted safety research making use of these facilities to study rural 2-lane highways. The principal objective of this project was to develop and test "dynamic remedial aids to reduce hazards and vehicle conflicts on narrow bridges."[9]

Another neglected transportation facility is "low-volume roads." These are rural dirt or semisurfaced roads that usually carry traffic of 10 to 100 vehicles per day, compared with the 50,000 per day typically carried by an urban Interstate highway and the 1,000 to 5,000 per day carried by the 2-lane paved highways discussed above. Of 3.8 million miles of U.S. roads and streets, 3.0 million are low-volume roads. And, of course, such roads are the main transportation systems of most underdeveloped countries. They have received precious little attention from transportation researchers; they are too unglamorous. In June 1975, the TRB held a workshop on low-volume roads to try to meld design and operational practices with planning and economic considerations. Sponsoring or cooperating agencies included the U.S. Forest Service, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, the Idaho Department of Highways, the Agency for International Development, and the International Bank for Reconstruction and Development.[10]

Urban rail transportation is another area where the glamorous technologies have overshadowed more mundane solutions. The TRB, at the request of the Urban Mass Transportation Administration of the Department of Transportation, convened a conference on light rail transit (LRT) in June 1975. LRT is a technology that covers transportation demands in the range intermediate between ordinary streetcars and rapid transit, or subways. LRT has a substantial cost advantage over either street buses or subways in those cases where the capacity needed is about 5,000 to about 30,000 people per lane per hour. Net capital costs are typically $4 million to $7 million per mile for LRT, compared to $30 million to $50 million for heavy rail transit.

The important point is that the potential need for this form of transportation is probably much greater than for subways, which are economic only in the most densely urbanized areas. LRT may become even more important if the trend toward decentralized population distribution continues, e.g., toward lower urban densities and moderate-sized towns. Light rail transit is extensively used in Europe, as it once was in much of the United States and still is in the Philadelphia area. New systems are being planned for Rochester, New York; Dayton and Toledo, Ohio; and Vancouver, British Columbia. The study conference reviewed engineering feasibility, cost, and general economic considerations. The proceedings will be used to assist in assessing the potential of LRT in U.S. cities of the future.[11]

Under its broadened mission, the responsibility of the TRB includes air and rail transportation, as well as pipelines and other transportation modes. This report, however, is not intended to be comprehensive, but only illustrative. For example, no mention has been made of the extensive study of the feasibility of meeting motor vehicle emission standards that was carried out under the auspices of the second Committee on Motor Vehicle Emissions.[12]

HOUSING, BUILDING, AND URBAN DESIGN

Although it is a distributed technology, transportation has significant centralized elements, with the result that transportation policy is somewhat more rationalized and technocratic than is policy for housing, buildings, and urban development. This is largely because the routes and terminals either are under public ownership, operation, and maintenance or are heavily regulated by government. For example, there is a decentralized network of competence in state highway departments, many of which have now transformed themselves into transportation departments.

The production of automobiles, ships, trains, and aircraft constitutes a highly centralized technology with a high degree of standardization of essential technological features. In contrast, housing and building represent the extreme of fragmentation, decentralization, and dominance by highly localized constituencies and interests. Only in the supply of building materials is there any degree of centralization and standardization, and even that is limited. Building probably needs to satisfy a wider diversity of interests and criteria than almost any other technology. Because the end product of building is site-specific and largely private in terms of the consumer, it is like the vehicle in transportation modes, but it is much more individualized because of the site-specific requirements.

Building suffers disproportionately large effects during business recessions, generally far greater than transportation. Early in 1975, for example, there were upwards of 650,000 unsold housing units on the market, and the situation was so acute that Congress legislated a $2,000 tax credit to stimulate the purchase of this housing. And in May of 1975, unemployment in the construction industry was 21.8 percent, compared to a national average of 9.2 percent.

At the same time, building is the object of an increasing array of regulations and restrictions encompassing environmental impact assessments for new developments, consumer product safety, occupational health and safety, disaster mitigation efforts, energy conservation regulations, and, of course, the classic areas of public health and safety regulation. Lacking anything corresponding to the relatively centralized and sophisticated state highway departments, the regulatory system for building—always highly fragmented—seems to be breaking down under the load of increasingly sophisticated and costly technical requirements. It is especially difficult for the system to adapt in a declining market and in the face of declining municipal revenues.

As a result of these and other factors, many observers are beginning to question whether the housing industry will ever be able to produce the number of units needed at prices that people can afford. Some foresee continued vulnerability to economic forces largely beyond the control of the industry. For example, in the first quarter of 1975, construction wages were rising at an equivalent annual rate of 9.5 percent, even in the face of the aforementioned high rate of unemployment. Furthermore, interest rates on mortgages did not decline with the reduction in prime interest rates.[13]

An increasing portion of the efforts of the Commission's Building Research Advisory Board (BRAB) is devoted to helping community planners and other elements of the building community cope with the new requirements in an orderly and responsive manner. A significant pilot study of selected communities has been initiated to examine the decision-making process in housing, building, and community development with respect to the environmental impacts of such development. The hope is to identify decision points in the planning process and relate them to those in the building and development process in order to help builders and others to anticipate and accommodate environmental impact problems and avoid costly revamping of plans to meet objections that should have been foreseeable. The ultimate aim is to improve the predictability of the planning process through better understanding of its requirements and rationale.

Another aspect of the regulatory environment of building is mitigating, through proper planning and design, the effects of natural disasters, especially floods and earthquakes. For example, federal flood insurance legislation now requires that flood-prone communities participate in the National Flood Insurance Program administered by the Federal Insurance Administration (FIA) of the Department of Housing and Urban Development. Under existing legislation, communities must, to be eligible for subsidized insurance rates, develop and have approved by FIA a land-use plan for areas identified by FIA as flood prone. If a community elects not to participate in the program, federally insured mortgage money will no longer be made available for any future construction in the community. BRAB, in cooperation with the Assembly of Mathematical and Physical Sciences (Office of Earth Sciences), has a Committee on the Prevention and Mitigation of Flood Losses, which is making a significant contribution to the development of criteria for various aspects of the Federal Insurance Administration's flood program. For example, there is a Panel on Flood

Insurance Mapping Criteria that is assisting FIA in determining what and how information should be presented on maps provided to communities to depict the height and areal extent of the flood hazard—and on which community land-use plans are to be developed.

Various other panels of the Committee are assisting FIA in establishing practices and procedures to be followed in technical studies conducted to determine the height and areal extent of flooding to ensure the best possible technical base for land-use planning. For example, a Panel on Flood Studies in Riverine Areas has been dealing with the sensitivity of the results of flood insurance studies to variation in the assumptions, practices, and procedures used in carrying out such studies for community planning purposes.

BRAB also plans to form a Committee on Practices for Mitigating Earthquake Effects in Buildings in the Eastern United States. Most public attention in the past has been focused on earthquake hazards in the Far West and Alaska, where recent earthquakes have dramatized the hazards of inadequate structural design. However, many parts of the eastern United States have also had major earthquakes within historical times, although the average interval between them has been much greater than in the West. Both Boston, Massachusetts, and Charleston, South Carolina, are considered to have earthquake risks comparable to that of the West Coast, but almost no work on seismic design standards has been undertaken in these areas. How much can be done remains to be seen, in view of the low visibility of the problem. Nevertheless, assessing the magnitude of the hazard and assessing the actions needed to reduce the hazard are worthwhile projects.

The issue of earthquake hazard raises fascinating sociotechnical questions of earthquake prediction. The Advisory Committee on Emergency Planning had a Panel on the Public Policy Implications of Earthquake Prediction, which completed a major report entitled *Earthquake Prediction and Public Policy*. There is general agreement among geologists that the capability of predicting major and minor earthquakes is near. As currently envisaged, this capability will permit the forecasting of the time, place, and magnitude of major earthquakes months or years in advance. Unlike the short-term predictions characterizing tornadoes, hurricanes, and floods, long-term earthquake prediction provides the possibility of instituting numerous long-range hazard reduction and disaster preparedness measures. Such long-term predictions may also lead to various adverse socioeconomic effects, the precise nature of which is currently unforeseeable. However, with proper utilization of earthquake predictions, many constructive measures could be taken to save lives, reduce property damage, and minimize social disruption.[14]

The advent of the energy crisis has rekindled interest in the solar heating and cooling of houses and other buildings. From about 40 solar installations in 1973, it is estimated that the number of such installations had grown to upwards of 200 by the beginning of 1975 and to as many as 400 by the end of 1975. The field is rich in innovation and entrepreneurial activity. But there is little solid information available about relative costs and performance characteristics of different designs. Builders and owners therefore hesitate to invest the capital necessary for installations—particularly for the retrofitting of existing buildings—without greater certainty about future energy costs, especially since present technology requires standby energy sources in most areas to span periods when solar energy is not available. Dissemination of information about workable designs is poor, and there is virtually no standardization.

The widespread adoption of solar heating and cooling also is inhibited by lack of a satisfactory technology for energy storage. Effectiveness of energy storage might be improved by the use of heat pumps to make use of relatively low-temperature heat, and work is intensifying in this field. However, this requires additional capital investment. A BRAB Advisory Committee on Solar Heating and Cooling of Buildings, which initially conducted studies for the National Science Foundation and now conducts studies for the Energy Research and Development Administration, has held workshops to collect experience in the utilization of solar heating and cooling technology.[15] The Committee hopes to continue its assessment of the potential for early commercialization of solar energy for space heating and cooling as well as for water heating, three uses that account for more than half the energy consumed in the residential and commercial sectors. In this context, solar energy can be thought of as a form of energy conservation technology, equivalent in its effects to other methods of reducing heat losses from buildings, and it must be assessed in competition with other less glamorous methods for reducing heat losses from buildings. In this domain the problem is not one of technological innovation, *per se;* rather, it is institutional innovation and political invention to remove the barriers to the application of a technology that will evolve under market forces once the initial inhibitions are overcome.

Reflecting the increasing emphasis on the "soft" aspects of building technologies, BRAB has a major program on Technology Assessment and Utilization. Under a supervising committee of the Board itself, this program has established seven "resource councils," each with about 20 members representing a wide variety of skills and perspectives. These councils deal with such issues as socioeconomic factors that will affect the nature of demand for building over the next 5 to 25 years, including demographic factors, life-style preferences, costs, and monetary and financing mechanisms; planning and design, including land-use policy; and production technologies, including productivity trends and the use of dimensional and functional coordination in building. This group of activities by the resource councils is intended to anticipate societal needs in the areas of housing, building, and planning for the rest of this century on both the supply and demand sides of the equation and to assess the implications of various technological means of satisfying those needs. Each of the councils has wide representation from the groups that supply, use, and are affected by building.

MATERIALS

Unlike transportation and building, the field of materials seldom interfaces directly with the public. Materials are, for the most part, "intermediate goods" that enter into almost every phase of economic activity. In recent years the materials industries, from mining to fabrication, have constituted a declining fraction of the GNP and of value added in manufacturing.[16] Yet innovations in materials properties or processing have been the basis of many innovations that have affected the consumer directly or have changed the character of the economy. The electronic and computer revolution has been based on materials technology.[17] Most advances in the productivity of the construction industry owe their initial impetus to materials innovations.[18]

The mining, extraction, and processing of materials probably accounts for about 25 percent of all the energy consumed in the United States and other developed countries.[19] After a century of declining relative prices of raw materials, we are beginning to experience a reversal of long-range trends, along with sudden concerns about shortages of materials resulting either from physical limitations or politically contrived ones, such as cartels. Debate rages as to whether the industrial part of the world faces a long-term shortage of basic materials, or whether advances in technology, including substitution and recycling, will eventually overcome shortages, despite temporary politically induced shortages.[20]

The National Materials Advisory Board (NMAB) deals with all aspects of the materials cycle from extraction to final disposal. Recently it has concerned itself particularly with materials problems related to the national energy program [21] and with possible measures for substitution or conservation of materials such as chromium, which the United States now obtains from foreign sources that are undependable for political reasons.

The NMAB also is dealing with the handling of hazardous materials. It necessarily cooperates closely with many of the other boards of CSS, since materials are an important source of innovations in transportation, building, and shipbuilding. One committee of NMAB has examined the fire safety aspects of polymeric materials, an increasingly important topic as more stringent fire safety requirements are legislated.

SOME TECHNICAL INNOVATIONS

There is not space to review the full spectrum of CSS activities; the result would be a mere catalogue, with little information. In the examples cited above, emphasis has been placed on economic, social, and political factors, because until quite recently these have tended to be slighted in past NRC activities. One should not infer from this that CSS is not interested in purely technical innovation. A few interesting recent innovations in a variety of areas of concern to the Commission can be cited by way of example. Some of these the Commission had little to do with; they are mentioned purely for general interest. Others are innovations with which one or another unit of the Commission has been directly concerned.

The Ship Structure Committee of the Maritime Transportation Research Board supervises a contract research program on various aspects of structural ship design. A project of particular interest is the design and installation of a ship response instrumentation system aboard the SL-7 Class containership, S.S. *SeaLand McLean*.[22] This ship is a member of a new class of high-speed container vessels deemed to be necessary for the

United States to retain a competitive position in international shipping. "The instrumentation system is part of a research program . . . to evaluate fully, from both analytical and experimental approaches, the design and response of this unique vessel during the early stages of its development and deployment." By comparison of the results of analytical and computer simulation with field observations of structural responses in a seaway, a more rational system of ship design may be developed to permit bypassing expensive model testing.

The CSS has responsibility for the Advisory Board on Military Personnel Supplies (ABMPS), which advises the U.S. Army Natick Development Center. This center has developed an enzymatic method of converting cellulose to glucose. Originally developed as a waste disposal scheme, the process appears to have considerable interest as a possible source of both food and fuel derived from agricultural wastes. The process is described in an article in *New Scientist*[23] as follows:

> The Trichoderma (virides) is grown in a culture medium containing spruce pulp and nutrient salts. The culture is then filtered and the solids discarded, leaving a clear straw-coloured enzyme solution with a marked resemblance to American beer. The cellulose solution and milled newspapers are then placed together in a reaction vessel at atmospheric pressure and 50°C. The product is crude glucose syrup; the unreacted cellulose and enzyme are recycled. The yield of glucose is about 50 per cent of the original cellulose. It can be used in chemical . . . or microbial fermentation . . . processes to produce chemical feedstocks, single cell proteins, solvents or fuels like ethanol.

The ABMPS, at the request of the Natick Development Center, held a symposium on the subject in September 1975. The proceedings of the symposium, which was entitled "Enzymatic Conversion of Cellulosic Materials: Technology and Applications," are soon to be published.

TECHNOLOGY TRANSFER

The primary function of the NRC, particularly in the fields of interest to the CSS, is to promote technology transfer—or, more appropriately, the utilization of existing and new technology. The various boards and committees of the Commission serve as a forum for the dissemination of new technology to a diffuse community of potential users and appliers. The key to such a dissemination process is *evaluated* information. Ideally, the units of the NRC should serve as the filter that sifts the more important from the less important and brings technology into juxtaposition with problems. This function is especially important in dealing with distributed national goals such as those with which CSS is most concerned.

Information transfer is thus a very important part of the Commission's activities, and, indeed, the major boards of the Commission operate information systems (in the case of TRB and MTRB, a computerized system) specifically designed to make the relevant technical literature more accessible to potential users of the knowledge. These users represent an ever-broadening base of disciplines and institutions and are international in scope.

Surprisingly little is known of how well these, or other, technology transfer mechanisms operate, or how innovation really takes place, especially in the sectors of transportation, building, and maritime transportation. One of the Commission's tasks for the future is to better understand each of these social delivery systems in terms of the flow and utilization of technical information and in terms of contracts between different elements of the relevant "communities." By such studies it is hoped that ways will be discerned for improving the process and for accelerating technological change as well as for improving its responsiveness to social needs.

HARVEY BROOKS

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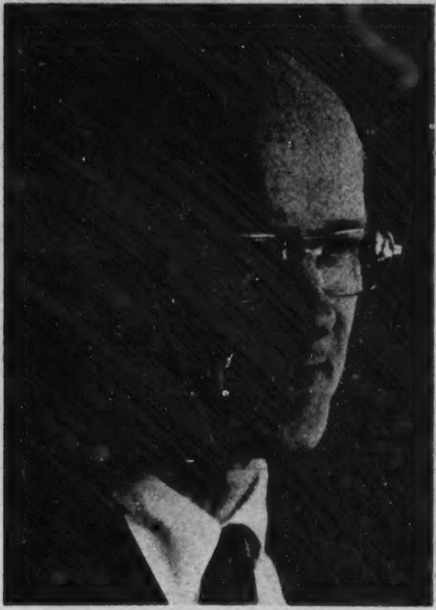

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Chairman, Commission on Human Resources

Commission on Human Resources

13

Are We Training Too Many Scientists and Engineers?[*]

Predictably, I can't provide a simple yes or no to the question posed in the title. There will be surpluses and there will be shortages in different areas of science and engineering, and the answer will depend on the quality and kind of education received, the ability of scientists and engineers to change fields, federal R&D budgets, new private and governmental technological developments, and so on.

Although there are serious methodological problems, I am going to try to say something of what we do know about manpower supply, demand, and the effects of demand on supply. To provide some focus, I will discuss only doctoral scientists and engineers.

SUPPLY OF DOCTORATES IN SCIENCE AND ENGINEERING

Table 1 shows that since 1950 there have been substantial increases in numbers of new doctorates in science and engineering.[1] However, the annual production of doctorates in the physical sciences has decreased since 1971, and in mathematics and engineering since 1972. The decline

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[*] I am indebted to many for information and advice for this report and especially to Dr. William C. Kelly, Executive Director of the Commission on Human Resources.

TABLE 1 Earned Doctorates in the Sciences and Engineering, 1950–1974

Year	Physical Sciences	Mathematics	Life Sciences	Social Sciences	Engineering	Total
1950	1,600	176	1,113	976	467	4,332
1952	1,731	204	1,357	1,266	570	5,128
1954	1,702	247	1,654	1,501	562	5,666
1956	1,621	228	1,518	1,499	579	5,445
1958	1,651	238	1,624	1,568	629	5,710
1960	1,861	291	1,728	1,668	794	6,342
1962	2,096	388	1,976	1,891	1,216	7,567
1964	2,527	589	2,362	2,255	1,664	9,397
1966	3,058	769	2,887	2,619	2,299	11,632
1968	3,667	970	3,696	3,490	2,847	14,670
1970	4,400	1,222	4,574	4,568	3,432	18,196
1972	4,226	1,281	4,984	5,590	3,475	19,556
1973	4,016	1,222	5,068	5,911	3,338	19,555

SOURCE: National Research Council, Commission on Human Resources, Doctorate Records File.

will continue (Table 2) because the number of first-year, full-time graduate students in these fields has also gone down.[2]

Since most of the graduate students who will receive doctoral degrees by 1980 are already enrolled, relatively accurate predictions of the doctoral production in the remainder of this decade should be possible. One uncertainty is that the fraction of first-year graduate students who actually complete their doctoral training will depend on their financial support, their perceptions of the job market for their skills, and the economy.

To project how many PhD scientists and engineers will graduate in the near future, Charles Falk[3] and his colleagues at the National Science

TABLE 2 First-Year Full-Time Graduate Students[a]

Field	1968	1973	Decrease (%)
Chemistry	3,719	2,667	29
Physics	2,736	1,808	34
Mathematics	3,106	2,289	26
Electrical engineering	3,243	2,660	18

[a] These data come from the National Science Foundation and include only graduate departments that responded consistently from 1968 to 1973. The coverage is very high.

TABLE 3 Projected Earned Doctoral Degrees

Year	Physical Sciences	Engineering	Mathematics	Life Sciences	Social Sciences	Total
1972 (actual)	4,200	3,650	1,300	4,500	5,000	18,650
1980	2,900	3,150	1,000	4,900	6,850	18,800
1985	2,050	2,500	650	4,900	7,050	17,150
Change (1972—1985)	−51%	−32%	−50%	+9%	+41%	−9%

SOURCE: Falk.[8]

Foundation have used models based on demographic data, recent trends in enrollments in both colleges and universities, enrollments in graduate school, and completion rates of doctoral studies. These projections indicate further major declines in annual doctoral production (Table 3) in the physical sciences, engineering, and mathematics, but not in the biological or social sciences. Falk and his colleagues emphasize that projections are not predictions and that projections produce a range of future situations based on definite assumptions and no significant breaks in trends.

Larger changes are projected for 1980 to 1984 than 1972 to 1980. But it is difficult to know how we should interpret trend analyses that far into the future, particularly when some of the trends on which the model is based are changing; for example, first-year graduate enrollments in engineering were up in September 1974.

DEMAND FOR DOCTORAL SCIENTISTS AND ENGINEERS

If percent employment is taken as a reliable indicator of demand, then the current demand for scientists and engineers is strong. A 1973 survey of 59,000 doctorate-holders (out of a total of 272,000 doctorate-holders in science and engineering in the United States) showed that only 1.1% of those in science and engineering were unemployed and looking for work; this is essentially a frictional level of employment found even in good times. However, the unemployment rates among women were higher than among men with comparable training.*

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* These data come from the Survey of Doctoral Scientists and Engineers conducted by the Commission on Human Resources with the financial support of the National Science Foundation and the National Institutes of Health.

Doctoral demand is dependent on college and university enrollments and federal and industrial research and development expenditures. Barring major changes in our economy, the first factor can be predicted with some accuracy. This was illustrated in 1965, when Allan Cartter [2] first pointed out that a tapering-off in this decade and an actual decline in the 1980s of the college-age population will reduce the demands for new college and university faculty. Cartter's projections covered the total demand for faculty, not just for science and engineering.

Nevertheless, his projections foretell serious oversupplies in fields where most of the new PhDs have taken faculty positions, unless there are major changes in the number of doctoral degrees or in types of jobs taken. Recently, Cartter has revised his projections of college and university faculty positions downward because a smaller fraction of high school graduates are now going on to college.

Two factors that could blunt the impact of Cartter's projections are (a) increases in continuing education, part-time education, and non-degree-credit education using doctorate-holding faculty; and (b) growing use of the doctoral degree to enter positions not previously requiring a doctorate.

However, the problem of too many PhDs looking for fewer jobs is broader than simply fewer faculty positions. For example, Falk of the NSF projects [3] that in 1985, 375,000–400,000 holders of doctorates in science and engineering will be in the labor market, and there are only 295,000 positions of the type usually held by science and engineering doctorates. The breadth of the gap will vary from field to field. But whether the specific numbers in the Falk and Cartter projections are correct or not, they remind us that the slowing in faculty growth in the remainder of this decade and the possible decline in the next decade will have an impact—perhaps a painful one—on new doctorate-holders and on those already employed who want to change jobs. As Philip Handler has noted, "markets for new scientists are saturable." Departments or programs training doctoral candidates primarily for faculty positions should examine the nature and size of their programs and the advice they are giving to students on job opportunities and types of careers.

Federal research and development expenditures are another factor in estimating doctorate demand. Federal R&D budgets (in constant dollars) peaked in 1968 and have kept to a steady level over the last 4 years. Future manpower needs will be affected by R&D budgets and by the initiation of new national programs. It is not at all clear what these programs will be, although it is safe to say that they will include work on the solution of our energy problems within environmental constraints, medical research and service, and natural resources.

Given these changes in demand, what effect do they have on supply? What effect does a reduction in the number of new faculty positions have on graduate enrollments? On determination to finish the PhD? On the type of PhD program selected? Richard Freeman and David Breneman[6, 7] argue that a number of "market" factors affect the production of doctorates: employer decisions, attitudes of experienced personnel, faculty advice, salaries, hiring practices, unemployment rates, and so on. They point out that the response to market forces is not simple, but rather tends to oscillate from shortage to surplus with a periodicity of 5 to 6 years, or about the time it takes to get a doctoral degree. There is a growing awareness that market effects need to be taken into account, and in 1974 a Subcommittee of the National Science Board released a report, *Scientific and Technical Manpower Projections*, that recommended the use of market models.

SUPPLY–DEMAND STUDIES BY PROFESSIONAL SOCIETIES

Supply and demand for doctorates in specific fields has been analyzed by several professional societies. The American Chemical Society's Committee on Professional Training, chaired by Herbert Gutowsky, has queried all doctorate-granting departments in chemistry on their plans for expansion or contraction. The departments were put into four groups taken in sequence according to their rank order (Group 1 was the top rank) in the Roose-Andersen Report of 1970, which rated the qualities of graduate faculties and effectivenesses of doctoral programs. The Committee concluded[8] that "many of the Group 3 and 4 programs should reassess the relative importance and quality of their undergraduate and graduate programs, and rededicate themselves to high quality undergraduate programs." The annual production of doctorates in chemistry has decreased from a maximum of 2,200 per year to 1,900 per year, and the sizes of the first-year graduate classes indicate that by 1980 about 1,600 doctorates will be produced per year.

R. D. Anderson[9] has written a series of articles on doctorates and jobs in mathematics. In his 1974 report he pointed out that there has been a reduction from 661 to 510 in the annual number of pure mathematics doctoral degrees between fiscal years 1972 and 1974. He concludes that "with a prospective ten-year steady state annual employment demand of perhaps 200–300 pure mathematics doctorates (for long-range retention), we should continue to reduce the numbers getting degrees until we are much closer to equilibrium." It is harder to get data on doctorate production in applied mathematics, statistics, computer science, and operations research, because these degrees are given in a variety of departments. A significant fraction of doctorate-holders in these areas are employed in industry and government, and so the job market is quite different from that for pure mathematicians.

Lee Grodzins has studied the supply and demand of physicists in great detail. The production of doctorates in physics reached a maximum of 1,600 and is now down to about 1,450. The size of first-year graduate classes indicates that this figure may stabilize at 900–1,000 by 1980. Beyond that, Grodzins feels that it is not possible to make very good predictions without more information on future R&D programs on energy and other activities that employ physicists.

Recently, an NAS Committee on Astronomy Manpower, chaired by Leo Goldberg, published a report recommending that university astronomy departments should reduce production of doctorates by informing students of employment problems and by screening students before they enter graduate programs. It also recommends that departments offer curricula that provide the basis for mobility in the employment market.

C. Alan Boneau, Director of Programs and Planning for the American Psychological Association, says that "the academic job market is now operating in a very weak replacement mode for most of the [social science] disciplines" and suggests that "in terms of tomorrow's human resources in the social sciences, clearly there is going to be spillover of considerable magnitude."

The biological sciences bring us to studies currently carried out by the Commission on Human Resources. One is the study on biomedical and behavioral research personnel needs discussed on pages 159–162.

Another study of future needs for scientists and engineers is part of the NRC-wide analytical studies for the U.S. Environmental Protection Agency (see page 121). A committee chaired by Dr. Earnest F. Gloyna of the University of Texas, Austin, will consider a profile of manpower requirements, sources of manpower, and ways in which persons with a variety of scientific and technical competencies are brought into the work on environmental problems.

CONCLUSION

Several studies indicate decreases in the supply of PhDs in science and engineering in the next decade and in traditional positions that employ them. If these projections are accurate, adjustments will be needed by institutions of higher education and in the educational objectives of young people. Some problems may be reduced by transfers between fields. Doctorate-holders have always shown considerable ability to transfer between fields, in addition to demonstrating a wide range of skills beyond college and university teaching.

The new realities in the doctorate market will force changes in the nature of graduate programs. The quality of the educational experience is different in different departments, and programs differ in the extent to which they attract strong students and encourage them to feel that they can successfully undertake a variety of different activities and transfer from the field of their doctoral dissertation to another field. Since in the future a larger fraction of PhDs will be employed by industry and by government at various levels, and since a significant fraction will have positions outside research and development and teaching, changes in some doctorate programs are needed to better prepare students for these future careers. This does not mean that their basic education can be neglected, but it does raise the question of how their graduate education can prepare them for the types of job opportunities they will have and how it can provide a basis for field transfers and changes in work activities in the future. To improve communication, it would help if universities had more visiting professors from industry and government and if industry made it possible for more faculty members to spend time in industry.

We do know something about future demands for doctorates and future supply of doctorate-holding scientists and engineers, but far more research is needed to reduce the major uncertainties. Some necessary readjustments may be taking place, but there is a danger of overreaction that will handicap future efforts to solve our problems in energy, materials, food, and environment. At best, we can foresee needs for technical manpower only a few years in advance, and so doctorate-holding scientists and engineers should, like others, be prepared to change fields and work activities during the course of their careers.

Finally, we ought to remember that tools for projecting manpower supply and demand are still somewhat primitive and the results often skewed by events. Some of the obstacles to useful projections listed by Hans Landsberg of Resources for the Future, Inc.,[10] apply equally to the projections cited in this article:

> the difficulty in foreseeing the direction and speed of technological change
>
> the emergence of new societal perceptions and goals, such as environmental considerations
>
> changes in major parameters, such as the rate of population growth
>
> . . . the reliance on relationships of which the inherent logic is not understood but which seem to offer convenient calculating opportunities.

ROBERT A. ALBERTY

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Study Project

PERSONNEL NEEDS AND TRAINING FOR BIOMEDICAL AND BEHAVIORAL RESEARCH

Seventeen people were awarded NIH fellowships in 1938 to do fundamental work related to cancer. They were the first. In 1968, $178.5 million was spent by the National Institutes of Health and the National Institute of Mental Health for biomedical and behavioral research training, either for fellowships or training grants.

Although fellowships were the original support mechanism, the training grant has become the more significant form of graduate student and postdoctoral support by NIH; of the 94,000 people who had, by 1972, received training support, more than 70 percent started on training grants.

Determining the value of this investment is not easy, but available evidence shows it has provided a critical mass of highly trained MDs and PhDs who do research and who largely account for new insights and rapid exploration.

But rumblings were heard in the late 1960s. Assurance was demanded that national investments in biomedical and behavioral research training are effective and produce commensurate return. There was concern that while surpluses in some fields were apparent or in sight, people were still entering them and receiving research training support; that some research trainees entered clinical practice on completing their training rather than continuing research; and that, in the case of training grants, a significant portion of the grant was being used for institutional purposes rather than for the support of individuals. In all, there was considerable pressure to alter the scale and form of federal support for biomedical and behavioral research training.

The result was the National Research Act of 1974. Public attention was largely attracted to the portion of the Act regulating the conduct of fetal research. However, the other portion, setting forth new rules for the support of biomedical and behavioral research training, promised equally important and perhaps more lasting effects. Philosophically, the law was reassuring since it reaffirmed the principle of the training grant and stressed continued excellence of biomedical and behavioral research. Practically, it mandated a number of novel changes. The separate training grant programs of NIH and the Alcohol, Drug Abuse, and Mental Health Administration (ADAMHA) were coalesced into a single program, the National Research Service (NRS) Awards. Two strictures were applied to these awards: They could not be awarded in particular fields unless there was a need for research personnel, and they had to be paid back, either by services or by dollars, plus interest. These provisos became effective July 1, 1975.

The law also directed the Secretary of Health, Education, and Welfare to inquire of the NAS if it could, *inter alia,* assess national needs for biomedical and behavioral research personnel, review NIH and ADAMHA training programs, and in general help them fulfill the needs criterion for the National Research Service Awards. As stated in the National Research Act, this provision meant that the Academy, if it agreed, would assess

> (A) the Nation's overall need for biomedical and behavioral research personnel, (B) the subject areas in which such personnel are needed and the number of such personnel needed in each such area, and (C) the kinds and extent of training which should be provided such personnel. . . .

The questions directed to the Academy were obviously difficult. It takes an average of 5 years after the baccalaureate to provide predoctoral training for research and 1 or 2 years of postdoctoral training for MDS or

PhDs who switch fields. Thus, in 1976, the National Research Council would have to estimate needs several years in the future, and would also have to estimate the required resources, public and private.

Part of the NRC assessment will necessarily include an examination of pertinent fields of research, established and emergent, and what their future requirements for personnel will be.

Of course, intelligent people, highly trained in basic sciences, adept at doing their own research—a reasonable description of the population given research training support by NIH and ADAMHA—are adaptable. They can, and will, follow leads into new fields, picking up new techniques and information as need be. So, the NRC must also consider the possibility of field changes and their effect on the supply of doctoral researchers.

Another consideration in the study is the precision with which research personnel needs in different fields can be projected. Some of the difficulties were described in a report on the study's feasibility issued in February 1975:

> In contrast to the problem of forecasting aggregate manpower in large fields, estimating needs by fine fields is exceedingly difficult. Boundaries between disciplines have become less distinct with the increase in emphasis on study of biological phenomena at the molecular level. Titles of narrow disciplinary fields have therefore lost some meaning for the purposes of forecasting. The problem is compounded by the difficulty of predicting major scientific developments and their impact on manpower requirements. Moreover, many aspects of the dynamics of the manpower pool are not clearly understood and, hence, any supply/demand model that can be developed will have limitations for determining the need for disciplinary specialists. These limitations, the Committee believes, are offset largely by the breadth of training and capability of biomedical and behavioral scientists and their capacity for mobility within and across fields.*

This continuing study is not just an attempt to match manpower supply and demand in biomedical and behavioral research. That would be simpler than the real task, which includes projecting emergent fields in biomedical and behavioral research that will become important and estimating how many people with what sort of training will be required. Of

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* Commission on Human Resources. 1975. Report of the Committee on a Feasibility Study of National Needs for Biomedical and Behavioral Research Personnel. National Academy of Sciences, Washington, D.C., pp. 4–5.

course, supply-and-demand projections will be a necessary part of the exercise, and the study will have to cope with their imperfections.

Beyond the complexities of manpower supply and demand projections, there are other issues for the study to consider, including the relative weight given to fellowships and training grants. Fellowships are given directly to individuals, and their value is more readily apparent to the general public. Training grants, in addition to supporting a promising researcher, may also be invested in faculty salaries, new instrumentation, lab space, computer time, and so on. These are necessary expenditures for high-quality training, but the public does not always understand how they are related to the quality of a particular student's research training.

The Committee in its first report* favored training grants as the principal support mechanism. It recommended that federal training support be maintained in fiscal year 1976 in the biomedical and behavioral sciences at fiscal year 1975 levels, for both predoctoral and postdoctoral training.

There are more issues before the Committee, many complex and difficult, and some perhaps painful. Many biomedical and behavioral researchers were nurtured in a system that provided generous support to excellent students with good ideas. The system still exists, and there are still national needs for basic research. But the National Research Act states that federal support of research training should be linked to national needs for personnel. It is a change that is hard for many to accept. But, as the first report of the committee made quite clear, the research community in all its forms will have to respond to the new realities:

> Legitimate aspirations of institutions and departments can best be accommodated with an adaptive mechanism that recognizes new needs, establishes excellence as a governing criterion, and sets a high priority on flexible response.

Committee on a Study of National Needs for Biomedical and Behavioral Research Personnel, Commission on Human Resources. Committee Chairman, Robert J. Glaser of the Henry J. Kaiser Family Foundation; Staff Director, Herbert B. Pahl.

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* Commission on Human Resources. 1975. The 1975 Report of the Committee on a Study of National Needs for Biomedical and Behavioral Research Personnel. National Academy of Sciences, Washington, D.C.

GEORGE S. HAMMOND
Chairman, Commission on International Relations

Commission on International Relations

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The National and International Context

Beginning in 1950, there was explosive growth in the volume of scientific research throughout the world, with the United States leading the effort. In the late 1960s the rate of growth began to decrease rather abruptly. Nationally and internationally we are now in a period of readjusting the scientific life-style. Adjustment may be possible without great sacrifice of the rate of production of new knowledge if we look carefully at the way in which we invest in scientific research with a view to maximizing return on the investment.

The overall pattern of expenditure of human and financial resources must be scrutinized to encourage less wasteful concentration of nearly redundant efforts in narrow problem areas. It is not enough to look at proposed research just to see whether or not it is "new." We must also ask the more difficult question, "*How* new is it?" That applies to both national and international programs in scientific research.

In international scientific efforts, we should perhaps shift the emphasis from competition to cooperation, with special emphasis on *complementary* input by the partners in cooperative efforts. Outstanding examples of such programs already exist. They are found in work where the very high cost of facilities has forced joint effort, as in high-energy physics, and where there has been some clear political gain to be achieved, as in the U.S.–Soviet joint program in space exploration. An implied intent in the various bilateral agreements between the United States and many other countries is increasing the scope of constructive collaboration. The intent is good, but we must give careful attention to the details of execution. Ideally, we should emphasize international cooperation between laboratories that can bring complementary contributions to bear on common problems, thus allowing the definition of problems of greater scope than could be tackled by either group alone.

This principle can be extended to U.S. interaction with the less developed countries. Our style has been to help the scientists in the less developed countries to learn to do nearly the same kind of work we are doing, or were doing a few years ago. A better investment of development funds might be made in programs to develop science less imitative of our own work. Admittedly, this approach requires careful planning and considerable diplomatic sensitivity.

There is considerable international debate about the relative merits of establishing large research centers and of contributing to the development of local research capabilities. The conflict arises from the tendency of the proponents of each kind of activity to claim that their favored enterprises can deliver more than can reasonably be expected of them. An international institute, with a unique mission, can contribute new knowledge economically if it is well conceived and well managed. But sponsors of such institutes sometimes do themselves a disservice by claiming to contribute more than can be reasonably expected to general scientific and technical growth in developing countries.

Development of local centers has been very much in vogue in the western world during the past quarter century. New universities, government laboratories, industrial research centers, and so on have grown like weeds in the United States, in the nations of Western Europe, and in a few other industrially developed nations. There is now serious question about the wisdom of this trend. As the national economies slow down, there is great concern that the commitments have been too numerous and that decreased resources are now spread too thin. Recognition of this fact in the United States and some of its peer nations now seems like locking the barn door after the horse is gone.

However, there are ways in which we can put our experience in rapid development of new, local establishments to good use. First, we can exercise restraint, both nationally and internationally, in creating more new institutions to deal with new problems as they arise. Second, we should keep the goal of complementarity in mind as we work with developing nations, although this principle will not be easily implemented. There are imposing psychological and logistical barriers. When people from developing countries look to the United States for assistance, they have a natural wish to acquire from us those components of science and technology that seem to have worked best in this country. But single-minded emphasis on transfer of such capabilities may not be in the long-term best interest of either nation.

The proprietary interests of nations and private industrial concerns are a reality and serve some good purposes. We need to find ways of working around and within them, to assist the less developed nations to acquire their own proprietary resources to put into international exchange. This will require that we give special attention to encouraging the development of indigenous resources in other countries, especially when those resources are different from our own.

The United States may have assumed an overly generous posture in its international development programs. In any international activity we should insist upon an accounting of what each side will invest and what it hopes to gain. It would be foolish to attempt parity in the inputs and outputs, and it will probably continue to be necessary for the United States to put up the major portion of the money on cooperative programs with many poor nations. However, any situation in which one partner makes no financial investment whatsoever seems unsound. A small investment of scarce resources shows the serious intent of the minor partner and provides some protection against neglect of the work. The same should be true when the roles are reversed, as they now are in the collaborative programs with Brazil, Taiwan, and the OPEC nations. There is no objection to having another country foot most of the bill in projects that are primarily focused on their problems and to which the principal U.S. contribution will be people and their talents. But we should be willing to make enough of a cash investment to keep us honest in our intentions.

The biggest problems are in interaction with developing nations. Our record in this field is mixed. We have done reasonably well in agricultural and medical technology—not as well as might have been hoped for or expected, but not too badly. We have not done as well in industrial technology, perhaps because we shy away from creating many competitors as successful as Japan.

There are several outstanding problems in the technology part of our science and technology effort in international development:

- The costs of outright purchase are too high for many potential client countries.
- Sale of technology with a permanent lien on the yield becomes increasingly unpopular.
- We have worked hard to transfer science to developing nations with the blithe assurance that indigenous technology will follow; this is not consistent with our own national history and is now being regarded as fraudulent by some recipient nations.
- Successful technology transfer requires adaptation to local conditions, and we have yet to become expert in facilitation of such adaptation.
- The greatest need in some countries is for low- and medium-level technology in which the United States excelled 50 years ago, but which we have now largely lost.
- The greatest world need is for *new* technologies in developing countries and we have not begun to tackle this problem on a large enough scale, although the Commission's Advisory Committee on Technology Innovation has made a good beginning.

Many people fear that we are not getting a fair return on our investment in technological cooperation with the Eastern European nations, especially the Soviet Union. We should not make a fetish of trying to make the balance of information transferred exactly even, but we should try to maximize our returns.

Our strongest and most productive interactions are with Western Europe, Canada, Japan, Australia, and New Zealand. A free-flowing system has been developed, and on the scientific side, at least, the *status quo* is seen almost as a natural way of life. There is a relatively high satisfaction level with respect to technology exchange, and, as problems arise, they are usually treated as problems of economics rather than of technology. No profound reflection is required to convince one that questions of economics and technology are strongly linked; a corollary to this conclusion is that even scientific interaction may also be in for serious trouble. It is a fact that we spend a good deal of money on interaction with scientists of the "West," but it is difficult to do an accounting of what is spent and what dividends are returned on the investment.

Interaction mechanisms are almost innumerable. Very important in both science and cost are the superprojects: space exploration, studies of the oceans and atmosphere, the Antarctic program, and so on. There is also a slowly increasing number of international institutes, most of which now seem to be in deep financial trouble. There are countless international meetings, conferences, and symposia; in recent years the scientists of the world have moved around the world from meeting to meeting like flocks of migratory birds. Until very recently there was also a great deal of movement of young scientists, especially postdoctoral fellows, among the Western nations. We need an inventory of these activities and some assessment of their relative value so that the inevitable cuts in expenditures can be made wisely.

Any attempt at evaluation and planning should be carried on in cooperation with scientists and government officials in the other countries involved. In recent conversations with officers of Western European academies and similar organizations, it has been apparent that they are worried about the erosion of international scientific exchange and the haphazard way in which support is reduced. Interestingly, there seems to be nearly universal conviction among these people that there are too many international meetings and that they are generally poorly planned. There is also a surprisingly high level of interest in some of our own notions concerning complementary research collaboration, enough to show that we have no monopoly on such thinking. These leading academicians also share the fear that such ideas will be difficult to sell both to governments and to our fellow scientists, with the latter being the more difficult to deal with. If the perception is correct, there is a problem, because scientists will be the agents in carrying out philosophically changed programs, and any new plan that meets with general disapproval in scientific circles will probably work badly.

In conclusion, it is clear that we need to review philosophy and operations in our international programs, both nationally and institutionally. More attention should be given to the returns that we hope to receive from individual projects. There is probably a need for some move to coordinate, and perhaps centralize, our very diverse international relationships in science and technology.

George S. Hammond

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Study Projects

WORLD FOOD AND NUTRITION

On December 3, 1974, the President of the United States wrote Dr. Philip Handler

> to enlist the aid of the National Academy of Sciences in a major effort to lessen the grim prospect that future generations of peoples around the world will be confronted with chronic shortages of food and with the debilitating effects of malnutrition.

Explicit in the request was an examination of the role of science and technology. Paradoxically, the request was in part prompted by a food crisis in which technology or the lack of it *seemed* a minor element. Rather, the crisis appeared rooted in economic factors such as the uneven impact of grain prices on different economies, various political decisions, the inherent difficulty of *ever* balancing supply and demand for *any* resource, and weaknesses in the mechanics of the international food market. Thus, for a variety of nontechnological reasons, there has been since 1967 a depletion of the grain stocks of the grain-exporting countries, including the United States. At the same time, many of the developing countries were increasing grain imports. In 1972, poor weather reduced the yields of several major grain harvests, and world food production declined modestly—about 1.6 percent. Among the countries whose harvests were disappointing was the Soviet Union. That country—in a change from earlier policies, under similar conditions, of slaughtering animals and general belt tightening among its population—opted to buy massive amounts of grain, including a significant fraction of the 1973 U.S. wheat harvest. That action, aside from helping to raise meat prices in the United States, also further drew down any grain surpluses that might have been used to mitigate the plight of the Sahelian countries of West Africa or of India, Bangladesh, Indonesia, and other countries whose crops were substantially reduced by drought and whose people were suffering from serious malnutrition and starvation.

Other factors contributing to the food crisis included sharp and somewhat puzzling reductions in the Peruvian anchovetta harvest resulting ultimately in increased demand for soybeans; increased competition among the developed countries for more grain as animal feed so their citizens could eat more meat; and the deliberate choice of many developing countries to invest limited funds in industrialization, rather than in raising agricultural productivity. However, to view food shortages simply as a matter of economics—the result of failures of marketing and other systems—is to seriously misjudge the full nature of the problem and to overlook potentially effective responses. Growing more food, growing crops with increased resistance to weather and pests, and other responses amenable to technology can and must be a part of avoiding future food crises. Many of the developing countries, already hard pressed to feed their people, are being threatened by even greater pressures. It is in these developing countries that 86 percent of the world's population growth is occurring—a 2.5 percent average annual growth in population compared to 1 percent or less for the developed countries. The gap in food production per capita between developing and developed countries is widening, and unless food production can be increased, there will be even less food available per person in countries that already have rampant malnutrition and widening pockets of starvation. As a U.S. Department of Agriculture report [*] pointed out

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[*] Economic Research Service, U.S. Department of Agriculture. 1974. The World Food Situation and Prospects to 1985. Foreign Agricultural Economic Report No. 98. Washington, D.C., p. 1.

while the growth of food production was slightly higher in developing countries from 1961–65 to 1971, per capita progress was lower because their annual population growth was 2.5 percent compared with 1 percent in developed countries. Per capita food production in the developed countries in 1971 was 15 percent above the 1961–65 average and it dropped only slightly as a result of 1972's shortfall. But the developing countries were producing only 5 percent more food per capita in 1971, and the 1972 shortfall pushed them back to the per capita level they had reached a decade earlier.

To give an aggregated evaluation that may be wrong in specifics but probably correct in the meaning, the world's population, according to the United Nations, will rise from 3.8 billion in 1974 to 6.5 billion in 2000; to keep up, the annual growth rate of food production, now 2.8 percent, must rise over the next 12 years to 3.6 percent. The remarkable record from 1954 to 1973, when world food production increased at a faster rate than population, must be matched.

Ultimately, Thomas Malthus may be quite right in his dictate that "pervades all animated nature" and that states that the "power of population is indefinitely greater than the power in the earth to produce subsistence for man." That judgment has been kept at bay—in spite of a 450 percent increase in world population since Malthus pronounced it—principally by two developments: the opening of vast new farming lands—the American prairies, India's Punjab, the paddies of Southeast Asia; and the evolution of new technologies to increase the labor efficiency and productivity of agriculture—mechanization, pesticides, new hybrid varieties, fertilizers, large-scale irrigation, and so on.

About 30 percent of the world's arable land is now farmed, and, statistically, there remains a great deal of potentially tillable land. But much of it is of poor quality, and much of it is in semitropical and tropical regions and therefore often refractory to agricultural technologies primarily fitted to the fecund black soils of the temperate zones where most of the world's grain is grown. Thus, tropical soils, including savannahs and deserts, are often fleetingly fertile, thin and fragile, unable to hold nutrients as can the soil of a Nebraska wheatfield. Where there have been successes, as in the "Green Revolution," they have been somewhat adumbrated, mainly for institutional reasons rather than technological ones.

An increase in acreage seems desirable if food production is to be raised substantially. But there are limits. Technology must also be effectively applied—not only new technology but also existing technology fitted to different soils and local conditions. What can be done here is still uncertain. Scientific farming suitable for the developing countries, rather than simply a transfer of Western agricultural methods, is a comparatively recent and still scattered phenomenon, and effective ways to nurture it must be identified and applied.

But can the "have" nations significantly increase their grain yields? The better-quality farmlands are already being tilled, and new frontiers are few and poor, both in location and soil quality. The only real alternative appears to be raising yields per acre. Whether that can be done in the United States and other developed countries whose grain yields have multiplied spectacularly, particularly in the past three decades, is somewhat problematical. A 1975 NRC report, *Agricultural Production Efficiency*, warned of "clouds on the horizon," * pointing to some disturbing indicators, such as a tapering since 1965 of the rate of increase in crop yields per pound of fertilizer added. While there are equally reassuring signs that (for the near term, at least) agricultural production efficiency will continue to increase, the report did assert that for

> the long-range future, in addition to such controlling influences as climate, increases in agricultural output will depend largely upon research results not yet in hand. Output can continue to rise for many more decades only if additional technologies become available. And such additional technologies can come only from new research; it is the research discoveries evolving now that will significantly influence food supply in 1990 and 2000 and later.

The comment is an apt epigraph for the NRC study on world food and nutrition problems. The first part of this two-part study is complete: a 6-month effort, whose report has already been issued,† advising federal agencies on how they could move immediately to support the recommendations made at the World Food Conference in Rome. The second part of the study is a long-term, 24-month effort that is intended to reply more fully to President Ford's request to Dr. Handler that the Academy

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*National Research Council. 1975. Agricultural Production Efficiency. National Academy of Sciences, Washington, D.C., p. 5.

† Published by the Academy in December 1975, the report had three parts: the *Interim Report of the World Food and Nutrition Study;* an attached report on *Recommended Actions on Nutrition Research and Development*, prepared under the auspices of the Food and Nutrition Board of the Assembly of Life Sciences; and, separately bound but transmitted with the *Interim Report*, a report on *Enhancement of Food Production for the United States*, prepared under the auspices of the Board on Agriculture and Renewable Resources of the Commission on Natural Resources.

aid in a major effort by the United States Government "to lessen the grim prospect that future generations of people around the world will be confronted with chronic shortages of food and with the debilitating effects of malnutrition" and that the Academy "make an assessment of this problem and develop specific recommendations on how our research and development capabilities can best be applied to meeting this major challenge."

The President's letter re-emphasized the magnitude of the food problem. It is not simply a matter of remedying systems and institutional imperfections, but of searching for and applying innovative ways to increase food production.

Accordingly, the study will focus its final report on an integrated program to mobilize research and development efforts to increase food production and decrease malnutrition in the developing countries. Research will be the central element in the program, encompassing many elements beyond agricultural productivity: losses in moving food from field to market to consumer; food-raising requirements to meet specific and widespread nutritional problems; food processing; the role of weather and climate variability in productivity; and, perhaps most critical, how to organize R&D programs and institutions, in the United States and in the less developed countries, to attack these problems.

There is already immense activity on the food front outside the NRC; a variety of studies and task forces are seeking and producing information on and analyses of the food supply complex. The NRC in designing the study was quite aware of these efforts and of the need to avoid wasteful repetition. After considerable discussion within the NRC and with the federal interagency task force * cooperating with the NRC in the effort, it was agreed that a unique contribution can be made by the NRC in examining the potential of research and development for significantly increasing food production and combating malnutrition in all countries, and in suggesting a program to accomplish that purpose.

Study on World Food and Nutrition, Commission on International Relations. Study Chairman, Harrison Brown of the California Institute of Technology; Study Director, Joel Bernstein.

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* The task force is comprised of the Science and Technology Policy Office of the National Science Foundation (through which the contract is funded and administered), the Agency for International Development, the Departments of State, Agriculture, and Health, Education, and Welfare, and the National Oceanic and Atmospheric Administration.

A VISIT TO A CHINESE VILLAGE AND ARCHAEOLOGICAL SITE

A paleoanthropology delegation of eleven American scholars—archaeologists, anthropologists, geologists, botanists, and China experts—visited the People's Republic of China between May 15 and June 14, 1975. Their trip was sponsored by the Committee on Scholarly Communication with the People's Republic of China [*] and the Chinese Scientific and Technical Association. Traveling a total of some 5,500 kilometers by train, plane, and car during their 4-week stay, the Americans visited research institutes, museums, and universities in such cities as Beijing (Peking), Tianjin (Tientsin), Xian (Sian), Anyang, Chengzhou, Nanjing (Nanking), Shanghai, and Guangzhou (Canton). The delegation also had the opportunity to see a number of Paleolithic, Neolithic and Bronze Age sites. It is hoped that what follows—an account prepared by the delegation of its visit to the Ding Cun Paleolithic site—will give a sense of a "typical day" during the trip.

Ding Cun (Ding village) in southwest Shanxi Province is on the banks of the Fen River some 37 kilometers south of Lin Fen, the district seat, where we stayed. This region—some 600 kilometers southwest of Beijing as the crow flies (or perhaps we should say as the *bugou* flies, a bird which arrives a few weeks before the wheat harvest and whose haunting cry charmed us throughout Shanxi)—is traditionally associated with the capital of one of the legendary sage emperors who are thought to have ruled China in the third millennium B.C. It is a region that foreigners rarely visit—only groups from Korea, Cuba, and Albania had previously visited Ding Cun—so that during the course of our stay our convoy of cars and minibuses frequently drove through streets lined by crowds of smiling, clapping onlookers, some of whom had stood for long periods in the rain and the dark waiting for a glimpse as we drove by. It was a curious experience to find ourselves the center of such seemingly unmerited attention.

We arrived by steam train at 2:50 p.m. on May 26 after a comfortable 5-hour ride down the Fen River valley through a fantastically eroded loess plateau and were immediately driven to our hostel, a three-story cement structure, set back in a courtyard behind a guarded gate that was soon surrounded by an expectant crowd. After some refreshment, we set out by 3:50 p.m. for Ding Cun itself, speeding along a paved road lined with young poplars, as our drivers insistently blared their way through a variety of bicyclists, carts, trucks, and buses. The road ran parallel to a terraced landscape that descends in dissected loess to the Fen River. As elsewhere in Shanxi and Hopei, the yellow dust in the air obscured the sun, giving the sky a leaden look and penetrating hair, ears, clothes, and cameras.

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[*] The Committee was established in 1966 by the American Council of Learned Societies, the National Academy of Sciences, and the Social Science Research Council.

Turning off the highway and traveling about 2 kilometers down a dirt road (specially smoothed for us, as we later discovered) that ran toward the river, we arrived at the small, central plaza of Ding Cun, dominated by a large wall painting of workers of the world singing the "Internationale," the words painted beside it. At that time, we saw none of the village population. The village itself was immaculate. It consisted of a complex of houses and walls built of brick and rammed earth, the walls frequently whitewashed (and painted with slogans—e.g., "For industry study [Da Qing]"; "For agriculture study [Da Jai]"; "The whole country studies the People's Liberation Army"), and all divided by narrow alleys and an occasional ornamental gate. From an upper balcony we were given a panoramic view of the village with its gray tile roofs; every level plot of ground terraced into the eroded loess plateau surrounding the village was under careful cultivation, much of it in winter wheat awaiting harvest. We then descended on Ding Cun's barefoot doctor and her aide, both women in their early twenties, who showed us the impressive rural pharmacy, examination room, and fully adequate supply of Western medicines (including antibiotics such as sulfonamides, penicillins, and tetracyclines; drugs such as procaine and adrenalin; and vitamins B_1, B_6, B_{12}, C, and K_3 in both injectable and oral form), as well as its large supply of traditional Chinese herbs. Of particular interest was a birth control chart on the wall indicating the number of births and deaths for the most recent years and the number of peasants using various forms of contraception. The barefoot doctor (whose surname was that of the village, Ding) won our hearts with her confidence and aplomb in answering our questions.

Next we crowded into several classes in the elementary school where we saw children doing fractions and learning how to read (since it was now about 5:30 p.m., we guessed that the children had been kept in class specially for us). The wide-eyed younger children were remarkably well-disciplined as the teachers led them through their recitations and as they sang a song and then applauded us. One of the great pleasures of visiting China was to see the friendly and totally charming Chinese children; we left that classroom, as we were to do many others, with broad smiles on our faces.

We next visited the quarters of city youths who had completed Middle School and had "volunteered" to serve for 3 or more years in Ding Cun to help the peasants and to learn from them. Three or four lived in a room; the rooms were sparsely furnished, with volumes by Marx and Engels (in Chinese) by the beds. After a trip to the kitchen where we saw *man tou*, the north China "bread," being made, we returned to the long meeting room, with its whitewashed walls, where we sat with our hosts at two long rows of tables, under bare electric light bulbs, with the portraits of Chairman Mao at one end of the room and of Marx, Engels, Lenin, and Stalin at the other. Our hosts were the local cadres attached to the Revolutionary Committees, Bureaus of Cultural Affairs, as well as the Ding Cun Cultural Relics Preservation Team. It was typical of the care with which we were treated that two members of the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP) had come by train from Beijing in order to show us the site. Another member of the IVPP, who spoke English, traveled with us throughout China.

As we sipped tea and wine and nibbled on wine-soaked dates (a local product), we were given a detailed account of the Ding Cun production brigade and the history of the archaeological site. We learned, for example, that the peasants earn about 1 *yuan* (57 cents U.S.) a day; that the average household savings were 150 *yuan;* that there were 950 people in the Ding Cun production brigade, with 140 big animals and 224 pigs; that over 100,000 trees had been planted; that illiteracy has been eliminated; that each house has electricity; that the population has doubled since 1949; that private household plots do exist, but they are now cultivated collectively; and so on. We were told that, thanks to the leadership of Chairman Mao, life had improved immensely since liberation, and the evident prosperity of the village supported this convincingly.

Tired after our train ride and tour of the village, we were glad when the orientation session was brought to a close around 7:30 p.m. and we rode back to Lin Fen in the dark through the usual curious crowds, some running beside the minibuses for a longer look. Dinner with our Lin Fen hosts was a staggering banquet of local delicacies (such as golden ingot eggs). Another of the great joys of touring China is the cuisine, and the dinner that night in Lin Fen was superb.

Pressed for time, we breakfasted at 6:30 the next morning (surviving a minor misunderstanding about Western tastes—heavily sugared "coffee-tea" served as one drink) and were back in Ding Cun by 8:00. We left the vehicles soon after leaving the highway and walked at our leisure down the dirt road, which at this point paralleled a ravine deeply eroded in the loess. The steep walls, about 60 meters high, provided excellent exposures of the loess and its varied soils, some of which we examined close at hand in the roadside banks. We passed through the village where we could see the villagers—our first glimpse of the village population—held back at the far end of the street and walked down through the fields to the archaeological localities, which lie scattered on the western banks of the Fen River. The localities were of great interest to us because of their postulated age (Late Pleistocene) and the association of stone tools, fossil animal bones, pollen, and human fossils, which might permit rather detailed reconstructions of past climates, environments, and human adaptations.

The first group of sites was in a cultivated area along the single track of the Taiyuan-to-Xian railway. Prompted by finds originally made by peasants in 1953, local archaeological teams have found some 2,000 stone instruments, 28 species of fossil mammals, 30 molluscan species, and several kinds of fossil fish. (We had already examined some of these finds in the IVPP in Beijing.) These came from consolidated sand and gravel that lies gradationally below the loess, about 15 meters above the present river. Because of cultivation and grading, the deposits that produce these artifacts and fossils were now covered, but we saw enough to comprehend their geologic character.

We then walked south for more than a kilometer along the railroad to Locality 100, famous among paleoanthropologists as the place of discovery of three human teeth, again from alluvial deposits, gradational below the loess. The geologists in our delegation agreed that this geologic section could be matched in general attributes with Late Pleistocene stratigraphy elsewhere in the world. During this archaeological ramble along the loessic banks we were accompanied by our hosts from Lin Fen, Ding Cun, and the IVPP. A case of *qi shui* (the Chinese soda pop) and a box of glasses had been carried down to the riverbank and Chinese and Americans all sat and drank beneath a tree. The barefoot doctor, who was gathering medicinal herbs as we walked, took the occasion to correct a mistranslation in the previous day's discussion that had given us an erroneously high figure for infant mortality in the village; it was clear that our questioning on this point the day before must have provoked discussion.

As we walked back through the fields toward Ding Cun at about 11:30 a.m., large numbers of peasants, male and female, bearing their hoes and other tools on their shoulders, sallied out of the villages and marched past us towards the fields, well-dressed, smiling, and occasionally clapping.

We drove back to Lin Fen at a leisurely pace, lunched, and, still coated with the yellow dust, caught the 3:00 p.m. train for Xian, the same train on which we had arrived just 24 hours earlier. And some 20 minutes later we were rolling past the archaeological sites where we had been so warmly received and had learned so much.

Ding Cun is undoubtedly a special village that has been prepared for foreign and Chinese guests; a printed color brochure, in Chinese, describes the site, and over 7,000 Chinese have now visited it. But the opportunity to stroll down dirt lanes in the Chinese countryside, to examine the loessic strata, and to see the site of major paleolithic finds, all in the company of Chinese experts, was a rare and agreeable one that permitted important scientific and social learning to take place. We saw the archaeological sites and obtained new insights for dating and evaluating the finds. But we saw more than that. The village of Ding Cun was not just the gateway to the archaeological site: it was, in the Chinese view, the necessary experience through which scientists must pass in order to understand that their work exists for, and is supported by, the people. This blend of scientific and social experience was typical, not just of our day in Ding Cun, but of our entire month in China.

Visit of Paleoanthropology Delegation to the People's Republic of China; Delegation Chairman, F. Clark Howell of the University of California, Berkeley; Staff Officer, Patrick G. Maddox of the Social Science Research Council, New York.

REMOTE SENSING FOR DEVELOPMENT

More than three years into the era of earth resources satellites, the United States is discovering that the heralded cornucopia of benefits is not to be gotten promptly or easily. First orbited in July 1972, LandSat-I (formerly designated ERTS-I) is a latecomer in the U.S. space applications program, whose initial goals were communications, weather monitoring, and, of course, reconnaissance. These earlier applications catered to well-defined, technologically sophisticated user communities, quickly able to assimilate and institutionalize the innovation. In contrast, the earth resource satellite programs potentially affect a great diversity of users, with a great diversity of management practices and data needs, and hence they face a correspondingly great diversity of problems.

In the technical performance of its principal sensor—the multispectral scanner—LandSat-I (joined in February 1975 by its twin, LandSat-II) has exceeded expectations; however, its first-generation design constraints—in spectral range, spatial resolution, and frequency of coverage—have limited the value of LandSat data in such sectors as agriculture and forestry. The bright promise of remote sensing from space for the United States has also been tempered by other factors: the difficulty of transforming remote-sensing data into information suited to existing decision models, and, more generally, of diffusing a new technology among a heterogeneity of potential users; and the reluctance of resource managers to convert well-established data collection systems to a source of uncertain continuity, in the absence of a firm U.S. commitment to an earth resources sensing program.

With these mixed returns, how should the United States respond to the keen interest that earth resource satellites have aroused in the less developed countries (LDCS)? What merits and effectiveness does—or will—remote sensing have for resource and environmental surveying in countries with scarce means—human, material, organizational—and one overriding ambition—economic development? And what, if anything, should be done to help LDCS use this technology?

The Agency for International Development (AID) recently put these questions to the NRC Board on Science and Technology for International Development (BOSTID), which, since 1970, in a series of reports produced for AID, has examined aspects of science and technology bearing on problems of development. Though AID is sponsor and client, the studies are intended for the benefit of the international development community as a whole and are widely disseminated free of charge.

With the collaboration of the CNR Committee on Remote Sensing

Programs for Earth Resource Surveys, of the NRC Commission on Natural Resources, the Board established a Committee on Remote Sensing for Development. At BOSTID's request, AID agreed to a significant broadening of the Committee's terms of reference, for it soon became evident that consideration of space remote sensing in an international context introduces a host of complex and sensitive issues—e.g., legal, political, economic, operational, organizational—that would probably influence the development of a space remote-sensing system and its acceptability to the world community. In addition, the study would address such matters as the effects on LDC usage of technological change in space hardware and in ground data processing and analysis; the complementary role of aircraft remote sensing; and various options for institutionalizing the space and ground segments on some international and regional basis.

As the Committee learned at its first meeting, May 27–30, 1975, a score of LDCs have already taken significant steps to foster the use of remote-sensing data, and many others have had some experience with remote-sensing products and applications. Indeed, the LDCs' response to this new technology—by way of domestic policy initiatives, research and application activities, procurement of services from abroad, and resort to international organizations for help—suggests they have a more sanguine view of the utility of present-level LandSat imagery for themselves than the United States thus far has found at home. Several LDCs have already committed themselves to installing their own costly direct acquisition stations and related ground processing facilities, and others have indicated their intent to do so. Some LDCs are devising new institutional and operational machinery in the field of natural resources management for the processing and dissemination of remote-sensing data to user agencies.

To developing countries, often lacking even basic information about their national patrimony, LandSat imagery has proven to be a great and initially unanticipated boon. These countries found that imagery makes possible the rapid and inexpensive production of reliable small-scale maps, which, together with thematic overlays that incorporate data from aircraft and ground surveys, fill a vital gap in the planning and execution of many types of development projects and the structuring of a national resource inventory. Used especially for these purposes, and for defining water resources and the geomorphology of large areas, remote-sensing techniques may well hold more in store for the poorly charted and uncategorized developing countries over the next several years than for the developed ones. Remote sensing from space, by virtue of its synoptic, multidisciplinary character, may well induce, in addition, a more integrated LDC perception of their natural resource problems, with consequences for the way LDCS approach the management of their resources.

If space remote sensing serves needs of the LDCS that are different from those of the United States, are there implications for the evolution of the technology that should be taken into account? Should one consider, for instance, the development of a satellite system specifically designed and oriented to LDC requirements? Or should the emphasis be on strengthening and diffusing in the LDCS the ground-based capability to process and utilize imagery from a common satellite source?

These and related questions are being taken up in various international forums, particularly the United Nations, and thus will warrant examination by the NRC Committee. In weighing the future of remote sensing for developing countries, the Committee will also have to face concerns expressed by a number of LDCS (and by some developed countries). These nations see remote sensing posing a threat to

- Their concept of sovereignty, in that it constitutes an invasion of their national privacy
- The imperative of their security, in that open and universal distribution of imagery (upon which the United States and other countries insist) may reveal privileged facts relative to national defense or national resources
- The principle of equity, in that some countries, or elements within a country, will profit more from the technology than others, and perhaps at their expense
- The goal of participation, in that unilateral control and management of a global system (by the United States) creates a new condition of dependency of the many on the one, contrary to the aspirations of the world community

Initiatives in the United Nations to check these untoward effects are taking two routes: the adoption of an international legal regime with certain restrictive clauses and the establishment of institutional machinery variously endowed with management, regulatory, service, and other functions. Sound and timely or not, these initiatives illustrate the diverse reactions that remote sensing has evoked from the world community.

As an innovation, space sensing of earth resources presents opportunities and challenges on many fronts. Not the least of these, in the view of the Committee, is how a technology of global dimensions, its practical benefits aside, can be made to affirm interdependence and to promote international cooperation.

Committee on Remote Sensing for Development, Commission on International Relations. Committee Chairman, Harlan Cleveland of the Aspen Institute Program on International Affairs, Princeton, N.J.; Staff Officer, Julien Engel.

THE INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS

The International Institute for Applied Systems Analysis (IIASA) was chartered in 1972 and began operations in Schloss Laxenburg outside Vienna in July 1973. There are 14 member institutions:

The National Academy of Sciences, United States of America
The Academy of Sciences, Union of Soviet Socialist Republics
The Committee for the International Institute for Applied Systems Analysis, Canada
The Committee for the International Institute for Applied Systems Analysis, Czechoslovak Socialist Republic
The French Association for the Development of Systems Analysis, France
The Academy of Sciences of the German Democratic Republic
The Japan Committee for the International Institute for Applied Systems Analysis, Japan
The Max Planck Society for the Advancement of Sciences, Federal Republic of Germany
The National Centre for Cybernetics and Computer Techniques, People's Republic of Bulgaria

The National Research Council, Italy
The Polish Academy of Sciences, Poland
The Royal Society of London, United Kingdom
The Academy of Sciences, Austria (1973)
The Hungarian Committee for the International Institute for Applied Systems Analysis (1974)

There are some 60 to 80 scientists in residence at various times. IIASA and its programs provide an arena for cooperative work by East and West on common scientific and technical problems of modern societies, and IIASA's organizational management reflects this. The governing council, which is composed of one representative from each member institution and which has the responsibility of outlining the areas of research to be included in IIASA's programs, is chaired by Jermen Gvishiani of the Soviet Union. George Hammond, Foreign Secretary of the NAS, is the U.S. representative on the Council. The first director of the Institute was Howard Raiffa, who, upon his return to Harvard University in the fall of 1975, was succeeded by Roger Levien, formerly of the Rand Corporation.

IIASA's chartered objective is to "initiate and support collaborative and individual research in relation to problems of modern societies arising from scientific and technological development." IIASA's programs were to concentrate on "methodological and applied research in the related fields of systems analysis, cybernetics, operations research, and management techniques."

The initial programs specified nine projects, three being methodological—methodology, design and management of large organizations, and computer systems—and six being applied problem studies—energy studies, water resources, ecology and environmental systems, industrial systems, urban and regional systems, and biological and medical systems.

APPLIED PROBLEM STUDIES

Energy systems—IIASA's first project begun in 1973—is still one of the Institute's major activities. Led by Wolf Haefele, on leave from the Karlsruhe Nuclear Research Center in the Federal Republic of Germany, the project's medium- and long-range perspective blends an international focus with emphasis on planning and transition into new modes of energy production and use. Of significance for the decision maker, the energy project will offer a comprehensive synthesis of long-term policy choices.

The energy project emphasized nuclear technology in 1973 and 1974 and solar energy and the potential large-scale use of coal in 1975. Studies through 1977 will compare the previous options and will further investigate coal and geothermal power. Considerations of climate, energy demand, perception of risk, and installation siting are related research topics undertaken along with basic energy supply options. The increased demand for energy analysis and the mix of disciplines that comprehensive energy modeling requires have made the work especially appropriate for IIASA. Haefele, also IIASA's Deputy Director, points out that in studying solutions to energy problems analytical methods will be developed that have relevance to other problem areas.

The management of river basin systems was the initial concern in IIASA's water resources research. Led by Zdzislaw Kaczmarek, of the Polish Academy of Sciences, the project themes in 1975 were mathematical description of flood protection alternatives, water quality modeling, water storage and optimal allocation modeling, and the application of utility theory to conflict resolution problems in water resources. Turning from river basin management, the research emphasis in 1976 and beyond is on problems of water resources, such as pollution of inland seas, management of water for food production through irrigation, large-scale water transfers, and the water/energy interface in considering man's effect on the climate.

The ecology and environmental systems project, headed by C. S. Holling of the University of British Columbia, demonstrated, through practical and theoretical analysis, the benefits of integrating ecological science, modeling, and policy analysis—i.e., of developing a science of ecosystems management. A study of forest and pest management has been completed, and the techniques developed have been used in a study on multinational control of fisheries, with an initial focus on Pacific salmon. A case study assessing the effects of tourism, hydroelectric development, and urbanism on high Alpine regions was undertaken in cooperation with UNESCO. Significant ties with the United Nations Environmental Programme (UNEP) include joint sponsorship of exploratory workshops on particular problems. Dr. Holling has returned to Vancouver, and the environmental concerns of IIASA have turned somewhat from ecosystems management to analysis of detrimental environmental effects, with increased interaction with the energy and water studies.

The urban and regional project, started in 1974 and led by Harry Swain, formerly with the Canadian Ministry of State for Urban Affairs, initially focused upon national urban settlement systems, resource-conserving urbanism, and municipal systems. Work on management of urban emergency services—ambulance, fire, police—produced a useful survey for the urban managers. Further studies on national settlement strategies and regional development problems are of major interest to IIASA members and will be taken into consideration in future research planning.

In the other applied areas, the biomedical project examined broad population screening programs and examined ways in which resources for research to combat cancer can be optimally utilized in an international context. The integrated industrial systems project centered on the analysis of the most efficient use of resources in production congruent with a society's goals and constraints. Comparative methods of steel production provided a case study

METHODOLOGICAL STUDIES

In the methodology project, the major function is service to the various applied areas. The disciplines represented by the methodology team are wide. George Dantzig of Stanford University and Tjalling Koopmans of Yale University were IIASA's first two methodology project leaders. Michel Balinski of the City University of New York currently heads the methodology group. Leading themes in 1975 were mathematical programming and decision analysis, both of which have broad applicability to specific problems undertaken in the other projects.

Another support area has been the project on planning and management in large organizations, headed by Hans Knop of the National Economy Section, University of Economic Sciences, Berlin. An initial case study of the Tennessee Valley Authority started a series of studies of regional development, including the Bratsk-Ilimsk region in the Soviet Union. In the computer sciences project, in-house emphasis has been on computer networking, but computer-aided design and artificial intelligence have also been of interest to the project, headed by Alexandre Butrimenko of the Institute for Problems of Information Transmission, USSR Academy of Sciences. Working with the computer services department in support of the other projects, the computer science group reviews the status of computing at IIASA.

The Institute is sponsoring a major publication series surveying the state of the art in systems analysis (oriented to the practitioner) and a handbook (addressed to a wider audience). Dr. Levien has headed the survey since it was begun in the fall of 1974 and as Director of IIASA will continue in a major role with the project. Dr. Gvishiani is chairman of the Survey Editorial Board. The Survey/Handbook project is planned as a continuing function of IIASA, with updating of volumes as needed.

FUTURE PROSPECTS

In the view of the NAS Advisory Committee, IIASA's development and program achieved much more in only 2 years of actual operation than would have been anticipated. The general opinion is that the research effort must be concentrated but that the breadth of expertise of the resident scientists should be maintained.

Organizationally, IIASA is merging the initial projects (except for the survey) into four groupings: resources and the environment, human settlements and services, management and technology, and systems decision sciences. Two themes cut across the four research areas: (a) energy options for the year 2000 and beyond and (b) questions pertaining to integrated regional development. These two themes consume 50 percent of the research budget; the remainder of the budget is allocated to tasks in the research areas.

Finances are a difficult problem for IIASA. The charter established member contributions in dollar terms, with no way to adjust for inflation. Two devaluations of the dollar and inflation in Austria eroded the Institute's real income by almost 50 percent by 1975. A 20 percent dues increase in 1976 is a holding measure at best. Since the U.S. and Soviet contributions were originally each set at $1,000,000 and the other members' contributions at $150,000, the leadership of the United States in ensuring the Institute's financial viability is critical. That role is made difficult by the current funding situation in the United States, and especially in the National Science Foundation, which is responsible for the U.S. contribution.

IIASA's utility as an instrument of foreign policy is best evaluated by the White House, the Department of State, and the Congress. Indications thus far are that the cooperative efforts of leading scientists and institutions made possible by IIASA are leading to shared perspectives, which, if successful in even modest ways, will justify the hopes of the founders. As a special international endeavor, the Institute faces more complex organizational and research problems than a domestic research institution, which normally would not be evaluated before an existence of at least 5 years. However, although it is early in IIASA's history, a variety of reasons call for a thorough review of the scientific program. The NRC will be working in conjunction with the National Science Foundation, which hopes that a broad review can be initiated before the end of 1976.

Advisory Committee on the International Institute for Applied Systems Analysis, Commission on International Relations. Chairman, Alvin M. Weinberg of Oak Ridge Associated Universities; Staff Officer, Augustus Nasmith, Jr.

THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

The International Council of Scientific Unions (ICSU) is a nongovernmental organization of 17 autonomous international scientific unions and more than 60 national members—academies of science, research councils, and similar scientific institutions. ICSU's main function is to improve international scientific communication and cooperation. There are various ways in which the Council and the 17 member unions seek to do this. They hold meetings, sponsor publications, organize information and data services, and sponsor scientific programs, all for the purpose of catalyzing and spreading knowledge of new scientific developments as quickly, widely, and efficiently as possible. By standardizing symbols, units, and nomenclature, they seek to make international scientific communication free of misunderstanding. Since the ICSU represents all the sciences, it has an outstanding and perhaps unique capability for organizing interdisciplinary cooperation at the international level.

The ICSU is a nonpolitical organization, and it makes every effort to remain so, in spite of pressures from various national groups to take actions of a political nature. In line with its nonpolitical character, the ICSU maintains that scientists from all parts of the world have the right to participate in its activities, regardless of the political postures of their home countries. In union there is strength, and consequently the ICSU is often in a better position than its individual members to intercede with national governments and intergovernmental organizations when there is discrimination against scientists of a particular nationality or ethnic group.

The ICSU is also concerned about the problem of enabling scientists of developing countries to become a part of world science, that is, to enjoy the benefits of interaction with scientists around the world and to contribute to the common enterprise of increasing man's knowledge. The ICSU stresses that local scientific and technological competence is an essential element of economic and social development.

Finally, the ICSU is dedicated to the principle that science should be the servant of mankind and should be fully and imaginatively utilized to improve the human condition.

What is ICSU doing to achieve its goals? As space is limited, I will describe only two of the hundreds of programs, activities, and actions that can be identified.

Each year thousands of scientists from all parts of the world participate in scientific meetings, usually held for the purpose of discussing the latest findings in their fields of specialization. Not infrequently there are visa problems brought about by political polarizations between the nations in which meetings are being held and those in which particular scientists, who want to participate, live. Since World War II we have seen numerous "exclusion principles" act as barriers to free scientific interchange—e.g., East–West, two Germanies, Pakistan–India, Arab–Israeli, South Africa–Third World; visas have been refused scientists wanting to participate in particular conferences.

The ICSU has, as a matter of policy, intervened in many such cases, often successfully. In order to increase the effectiveness of such interventions, the ICSU Committee on Free Circulation of Scientists was created. It receives complaints, investigates individual cases, keeps records of problems, and informs meeting organizers what problems to expect if they accept invitations from particular countries. The Committee—now composed of representatives of the Royal Society (London), the French Academy of Sciences, the Soviet Academy of Sciences, and the National Academy of Sciences, and chaired by a member of the Swedish Academy of Sciences—has been quite successful.

A second example of ICSU activities is the Global Atmospheric Research Program (GARP), which is being planned jointly by the ICSU and the World Meteorological Organization (see page 95 for more on GARP). The goal of the program is to increase our knowledge of the circulation of the earth's atmosphere and thereby enable us to improve numerical models of the atmosphere used in weather forecasting and long-range climate predictions. Here, then, is a program that has the potential of both increasing scientific knowledge and benefiting mankind.

The first major undertaking of this program was the GARP Atlantic Tropical Experiment (GATE), which took place in the summer of 1974 and continued for 100 days, centering on an area of the ocean about one-third of the distance from Senegal to Brazil. The interpretation of the data amassed during the experiment is just beginning, but there are already signs that this research will have an important impact on thinking about one of the central problems of atmospheric science: tropical convection and cloud systems and their interaction with atmospheric circulation patterns.

GATE illustrates very well the advantages to our country of international scientific cooperation. Could American scientists have done this alone? In the first place, scientists of the United States and twelve other countries had the privilege of using the territory of Senegal as the base for their research. Day-to-day operations were planned in Dakar, where an American and a Soviet scientist shared responsibility for direction. From Dakar, more than 300 aircraft missions were flown to observe atmospheric phenomena. Obviously, this could not have been done without the full cooperation of the Senegalese government.

What about manpower and equipment? Most of the planes were American, but most of the thirty or forty ships were not; in the main, they were Soviet and British. What about cost? The initial cost of GATE was $50 million. Of this, our country covered 60 percent. Another 30 percent of the cost was covered by the Soviet Union, and the remaining 10 percent was paid by the other participating countries: Brazil, Canada, Finland, France, the Federal Republic of Germany, the German Democratic Republic, Mexico, the Netherlands, Portugal, Senegal, and the United

Kingdom. Note that three developing countries joined this effort. Also note that *all* the data collected through joint efforts are available to American scientists, and that therefore we obtained $50 million worth of research for $30 million.

The GARP program has clearly been a bargain to all concerned. In other ways and on differing scales, the other ICSU programs are bargains as well, not only for the United States, but for all mankind.*

Harrison Brown, *President*, International Council of Scientific Unions.

Governing Board of the National Research Council.

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* More information on ICSU activities is available from the Board on International Organizations and Programs of the NRC Commission on International Relations or directly from the ICSU Secretariat, 51 Boulevard de Montmorency, 75016 Paris, France.

II

INSTITUTE OF MEDICINE

DONALD S. FREDRICKSON
President (1974–1975), Institute of Medicine

17

Toward a National Health Policy

Lagging behind many other countries, including its neighbor to the north, the United States moves at a glacial pace toward a national health strategy. Yet its health system is bracing for a whirlwind of change, which, to some within the system, seems a harsh reward for decades of remarkable progress. Defenders of the status quo are right to remind us that the tuberculosis sanatoriums have been emptied, that vaccines and antibiotics have nearly banished the dread of fever in a child, and that so many of the diseases that we still cannot prevent are now at least correctable.

The principal motive for reform, however, is not the failure of the public to adjust its expectations to a slower tempo of conquest of the chronic diseases nor a revolt over the problems of access to a health system that has grown more complex and anonymous. The real national dissatisfaction with health care is with its soaring cost in dollars, a cost that increases faster than the general rate of inflation. To economists, the cost spiral seems particularly ominous because, if it is measured by changes in mortality rates or in longevity, there appears to be a steadily declining ratio of benefit to cost. Indeed, some economists and epidemiologists now view the effects of medical care as marginal and believe that other factors—such as housing, pollution, poverty, and crime—loom larger as determinants of the quality of life and of premature mortality.

This viewpoint only half persuades the politicians, whose scale of values is more practical. In the allocation of public funds, only defense and perhaps highways can match the priority accorded access of the citizen to medical care. To guarantee this access to larger and larger fractions of the population, more and more public money is required annually—increasingly from the federal government.

Because of its mounting role as guarantor of health care, and because of the strong remedies available to it, the federal government has become the single most compelling force for changing the health system toward greater cost-effectiveness. The question now is not whether but how completely shall a largely voluntary fee-for-service industry be converted to a prepaid, highly regulated public service system. The answer is not revealed in any generally adopted strategy. It is being determined largely by a series of political compromises. At risk of transformation in this process are the traditional ways in which physicians and other health professionals are trained, located, and paid; the content and style of professional practice and the nature of ethical and legal contracts between physician, patient, and society; the division of responsibilities between medical schools and universities; the financing, the management, the affiliations, and even the design of hospitals and clinics; and the support and emphasis of biomedical research and the growth and uses of medical technology.

Because of the complex issues of policy and conflict related to these pending transformations, the Academy created the Institute of Medicine in 1970. The Institute initiates studies both on its own and in response to requests from Congress or the executive branch. The present program consists of seven categories, which are interrelated and represent more a syncytium than isolated cells. These categories are the support and directions of health science research; education and manpower policies; assuring quality in health care; the financing and organization of the health system; reorientation of the system to a preventive mode; ethics, the law, and social choices; and the development of national health goals and strategies.

Some view of the breadth of effort is obtained from examples of projects now complete—a review of the National Cancer Program Plan; a groundbreaking study of the costs of educating physicians and other health professionals; detailed policy statements concerned with health maintenance organizations and quality assurance; conference reports on ethical and regulatory aspects of health care; annual reviews of the Administration's health budget; and a study of what is known about the medical effects of abortion.

The largest single study that we have ever undertaken is the most searching analysis ever made of the financial underpinning of hospital pregraduate and postgraduate training of medical and osteopathic physicians. The congressional charge for the Social Security Administration Study (now completed) relates to the ways Medicare and Medicaid funds are used to reimburse practicing physicians and residents during the complex interactions that provide medical care to patients while educating the next generation of doctors. Embedded in the charge also are questions about the dynamics of how some 1,500 teaching hospitals decide how many subspecialists of one kind or another they will turn out yearly, how federal funds influence the use of foreign medical graduates, and how the specialist chooses the location for his practice. The recommendations requested from the Institute cannot help but materially affect the structure and impact of national health insurance.*

Staff work has already begun on other projects pertaining to cost of health care, such as a study to find alternatives to adjudication of malpractice as torts and the now intolerable burden of amortizing the malpractice costs through the present insurance mode.

The Institute of Medicine feels a particular obligation to encourage scientific and health care institutions not to lose sight of the economic realities of health care costs in their decision-making processes and setting of priorities. No one should be allowed to forget the comparison in cost between a Drinker respirator and a dose of polio vaccine. However, biomedical research, the oldest continuous reform movement within medicine itself, sometimes has had the paradoxical effect of making health more expensive. The problem here is not knowledge, but the use of knowledge. One issue is the lack of satisfactory attention to predicting the effects of certain health technologies before commitment of vast resources to their development. This is one of the fundamentals of setting priorities in allocation of resources for biomedical research and

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* The report of the study, *Medicare–Medicaid Reimbursement Policies*, was issued in March 1976.

development. Another issue is the sometimes premature extension of discoveries to clinical diagnosis and treatment without assessment of effectiveness or continued monitoring to relate ultimate benefits to costs. When these benefits do not materially improve the quality of life of an individual or when the costs impinge unfairly on other priorities of society, the problems become ethical as well as technical.

One investigation that we are engaged in entails a harder look at the decision-making processes involved in human experimentation. The importance of these issues moves to a grand scale as large randomized clinical trials become increasingly important. Who can best reach the decision that sufficient collective doubt exists, and that the possibilities of getting answers are firm enough to begin a trial? What algorithms can be invoked in peer and ethical review procedures that preserve the possibility of honest inquiry while protecting human dignity and rights within the spirit and the intent of the law? How can the risks to subjects and investigators be indemnified?

Another important target for similar examination by the Institute is the available process for determining the efficacy of established medical procedures. Here is a pending series of difficult questions whose solution national health insurance is certain to make imperative. There is insufficient method, logic, and commitment to provide the answers.

Under its current grant from the Andrew W. Mellon Foundation, the Institute is enabled not only to examine the decision-making processes themselves but to explore the social dimensions and the long-range consequences of major technical, administrative, and political decisions affecting the health system.

Such analyses may, indeed, provide the process and the substance from which a coherent national health strategy or policy at last emerges.

DONALD S. FREDRICKSON

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Study Projects

MANPOWER POLICIES FOR PRIMARY HEALTH CARE

Primary health care is less available than it should be in much of the United States, according to increasingly intense comment by physicians, other health workers, legislators, government officials, and the general public. There is less consensus, however, on what functions are comprised in "primary health care" and who should perform those functions.

In mid-1975, the Institute of Medicine began an effort to sort out the policy questions, determine whether knowledge is available to help answer the questions, and come up with recommendations for public policy actions that can guide the development of a manpower supply for primary health care. The study is supported in equal shares by Institute core funds from the Robert Wood Johnson and W. K. Kellogg foundations.

Complaints about the inadequacy of primary care have arisen from such diverse but related situations as the inability of some persons to engage a physician, the feelings of others that the physician they do engage is not warmly enough concerned with their plight, and the rising price of medical care delivered by professionals whose post-high-school education may take up to 20 years.

Several modes of medical practice have appeared during the past decide to allay some of the concern about the disappearance of the legendary GP. Family practice became a specialty, and thus is more effectively competitive with other specialties in attracting medical graduates. Physicians' helpers were more formalized as products of training programs for physicians' assistants and nurse practitioners. Specialists in such fields as internal medicine, pediatrics, and obstetrics and gynecology expanded their activities as physicians of "first contact." And the idea of the health care "team" has been taken up in many settings in order to spread the work load.

Still and all, these developments in medical practice have not fully met the problems that evoked them, and, in fact, they have raised new problems. Family practice is only one of several models for primary care and has not demonstrably met the needs of the whole population. Physicians' helpers are proving very valuable but would be even more so if some wide agreement could be reached on what services they can perform under what supervisory arrangements. Health care teams seem to have a great potential for effectiveness in primary care, but first there has to be some consensus on who should direct the team. In sum, as the Institute's study plan states,

> because the functional responsibilities and role interrelationships among the many providers of primary care services are uncertain, it is not at all clear whether the diverse manpower initiatives currently being implemented by different segments of society are complementary pieces of a cohesive health manpower strategy that will, in fact, be able to meet future societal needs for primary care.

On a schedule that may extend 2 years, the Institute examination has begun with the assembly of a steering committee, which has the job of defining the study's principal issues. These might include not only such current concerns as physician maldistribution, but also questions of the "caring" function, disease prevention, continuity of care, integration of services other than medical, and the consequences of recent manpower developments, such as the family practice specialists and physicians' assistants.

The study's second phase will be the pulling together of information required for the committee's consideration of the policy issues previously defined. A beginning search of the pertinent scholarly treatises is providing some impressions about what does and does not exist among the numerous studies on one or another aspect of primary care. A few examples:

- Primary health care is a larger entity than primary therapeutic treatment; it also includes disease prevention and health promotion.
- Physician extenders (nurses or assistants) have been evaluated on the basis of structure, process, patient load, and costs, but not on the basis of outcome for the consumer.
- The decline in number of GPs has not been offset by the entry of specialists into primary care, but geographic distribution may be more crucial than physician numbers to the availability of primary care.
- Coordination of care often is compromised by inadequate organization and communication.
- The potential for primary care to reduce medical care costs, by providing ambulatory services in clinics as a substitute for some hospitalization, is not realizable under many third-party payments plans.

The third and final phase of the study is the steering committee's development of policy recommendations based, as the study plan states, on "consideration of 'what is' combined with expert professional judgment of 'what should be' in the supply of primary health care workers."

Committee on Manpower Policies for Primary Health Care, Institute of Medicine. Steering Committee Chairman, E. Harvey Estes, M.D., of the Duke University Medical Center; Staff Officer, Ouida Upchurch.

EVALUATING QUALITY ASSURANCE IN HEALTH CARE

In industry, quality control is now a large subdiscipline of the engineering sciences. In the health enterprise, however, quality control—more usually and optimistically called "quality assurance"—has not until recently begun to pull itself together into a field of study. The reality that quality assurance in health care *is* a field for considerable study has been underscored by the federal government's creation of a nationwide system of Professional Standards Review Organizations (PSROS), now being assembled to review the appropriateness and quality of institutional health services financed by the Medicare, Medicaid, and Child Health programs. The predicted nearness of some kind of national health insurance plan makes the study of quality assurance even more urgent, the presumption being that if government is to guarantee health care for everybody, it cannot entrust the definition of that care solely to the professions that provide it.

In mid-1975, the Institute of Medicine embarked on a year-long study to collect the scattered knowledge of the development of quality assurance programs for health care, evaluate the effectiveness of the many different predecessor programs that experimented with portions of the task now handed to PSROS, and, probably most important, identify the types of knowledge that are missing but needed to build an effectual system of quality control.

The study was contracted to the Institute by the Department of Health, Education, and Welfare. It is a lineal descendant of two paragraphs in Section 4 of Public Law 93–222, the Health Maintenance Organization Act of 1973. That entire section called for a sweeping assessment of health care quality assurance mechanisms, the construction of fundamental principles for the conduct of any quality assurance program, and even for the evaluation of quality from the standpoint of the consumer. The present study is only a portion of the grand investigation outlined in the HMO Act.

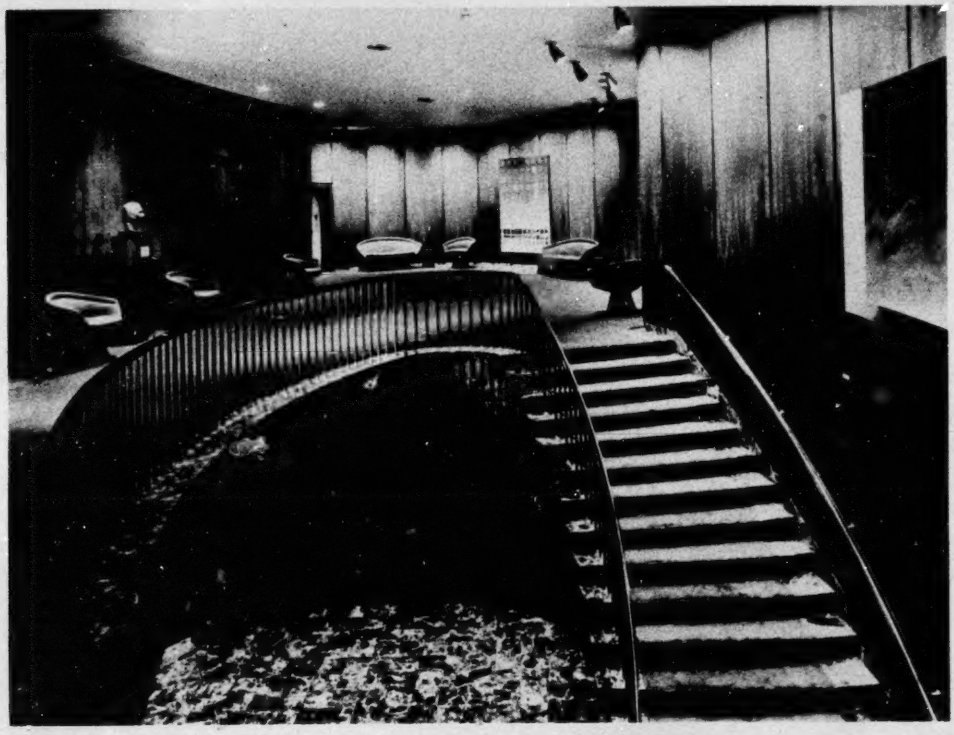
The present study also is a collateral descendant of two Institute-initiated activities undertaken after the enactment of Public Law 92–603, the Social Security Amendments of 1972 that spawned PSROS. The first was a year's study of policy issues involved in the establishment of PSROS or any other publicly sanctioned mechanisms for the review of professional standards for medical care. That examination, by an Institute panel headed by Dr. Robert J. Haggerty, then professor of pediatrics at the University of Rochester, resulted in a policy statement, *Advancing the Quality of Health Care*. The statement, published in August 1974, was a detailed discussion of principles fundamental to any quality assurance system, along with an exploration of the present state of quality measurement methods, the kind of data needed to determine the efficacy of health care, the variety of expertise that might be required to make judgments in a large-scale quality control program, the costs and benefits of quality assurance programs of various scopcs, and the ways in which quality measurements might be used to further education of health care providers.

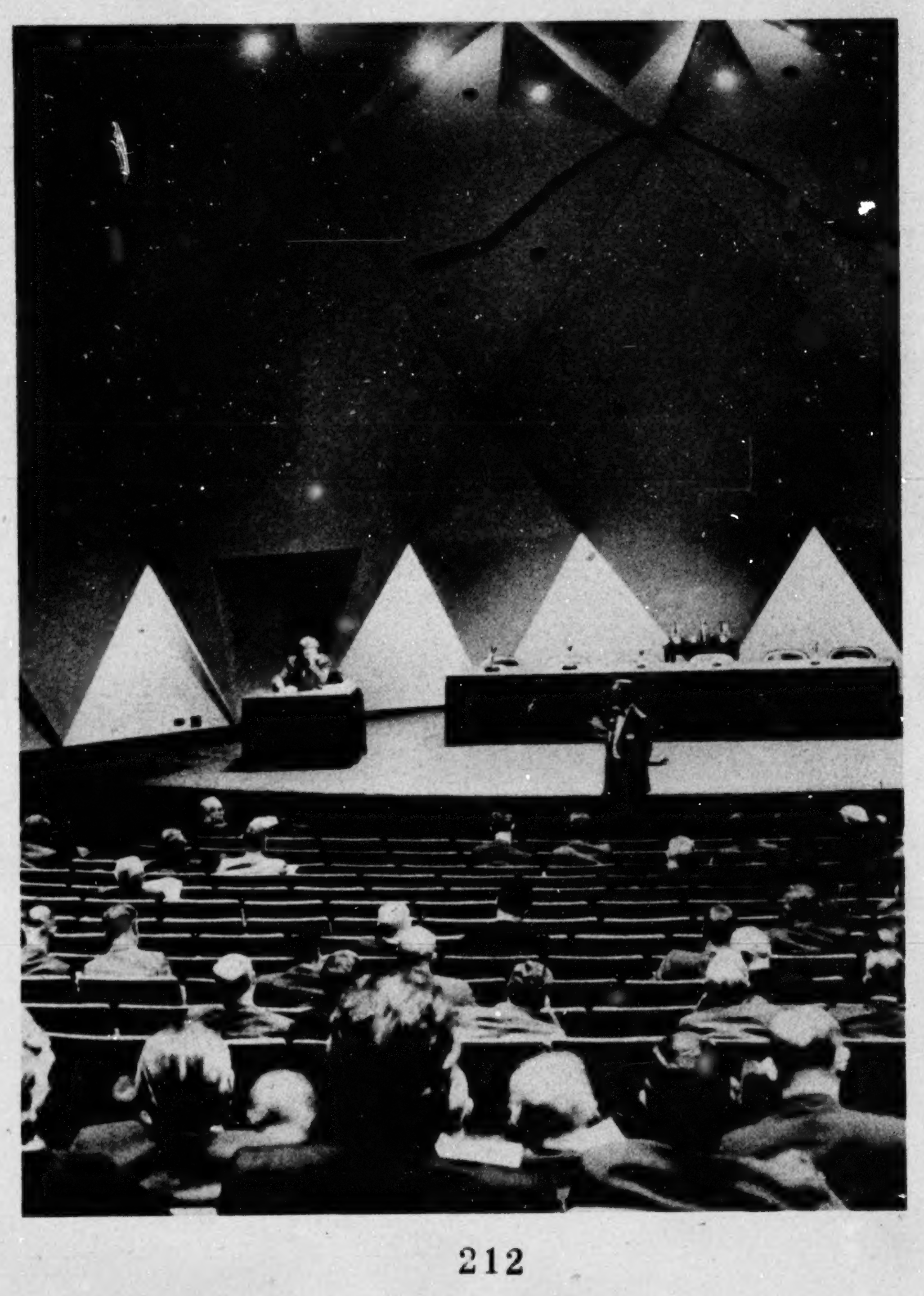
The second recent Institute activity antecedent to the present study was the November 1974 membership meeting, whose 1½-day program was entirely devoted to quality assurance issues. The keynote presentation by Dr. Avedis Donabedian, University of Michigan professor and pioneering scholar in health care quality assessment, suggested the job was far from done. The study of health care quality, he said, "is so complex and so much of it remains unexplored or known only by rumor or conjecture, that all I can hope to provide is a rough sketch that . . . points the way to further exploration into parts of it that now remain in partial shadow or virtual darkness." Nothing said by the succeeding speakers indicated any greater confidence in the existing knowledge.

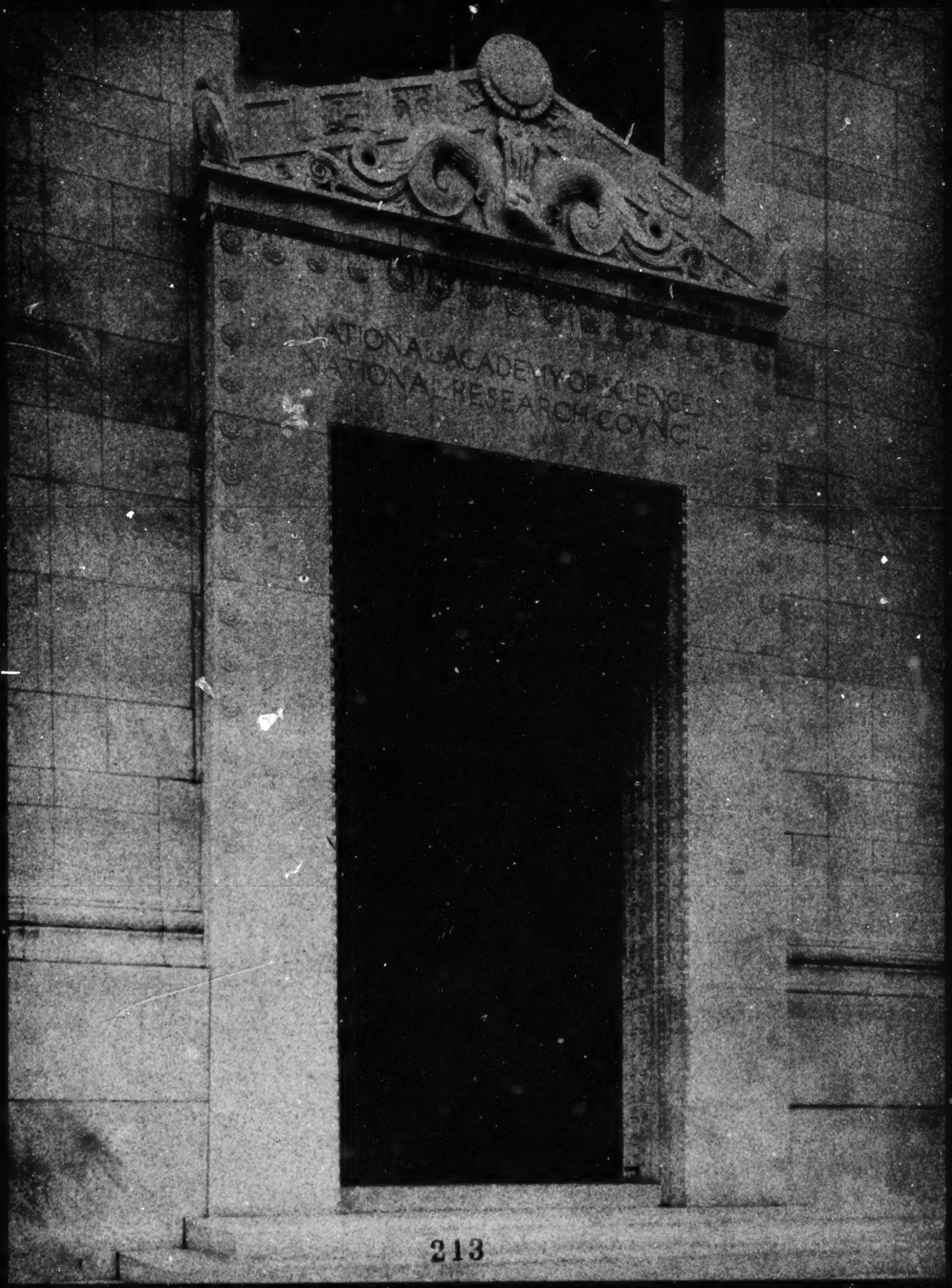
Additionally, long before the creation of PSROS, the Institute conducted as its first major study an examination of contrasts in health status, begun in 1969 by the Panel on Health Services Research of the Institute's predecessor, the Board on Medicine. The objectives of that study were to develop and test a methodology for comparing the effects of various forms of health care delivery on selected population groups. The study devised a method that used particular diseases as "tracers" of the quality of care received in various medical settings. The concept and technical details of the tracer method were explained in *Contrasts in Health Status,* Volume 2, published in June 1973. Volume 1, also published that month, was an assessment of perinatal mortality in New York City as a measure of the quality of prenatal care. Volume 3, published in February 1974, described a trial of the tracer method to assess the health status of children in a sample of more than 1,400 families residing in high- and low-income areas of Washington, D.C.

Against that background, the present study is, in the words of the contract, "to provide an explication and synthesis of current knowledge about the study and development of quality assurance systems . . .," as well as to evaluate the systems themselves and map routes to the most important territories now marked "unexplored." Along the way, the study may look into such specific matters as the application of quality assessment to ambulatory and long-term care; the effect of quality assurance programs on physician behavior and the comparative effectiveness of such feedback as sanctions, peer pressure, or continuing education; the cost of quality review in systems that otherwise appear workable; and the manner in which the consumer might be influenced to seek appropriate and high-quality medical services. In addition, as a shorter-term study-within-a-study, the reliability of discharge information that is abstracted from hospital medical records will be assessed to determine its usefulness for evaluation purposes.

Evaluating Quality Assurance in Health Care, Institute of Medicine. Steering Committee Chairman, Robert J. Haggerty of the Harvard School of Public Health; Staff Director, Linda Demlo.



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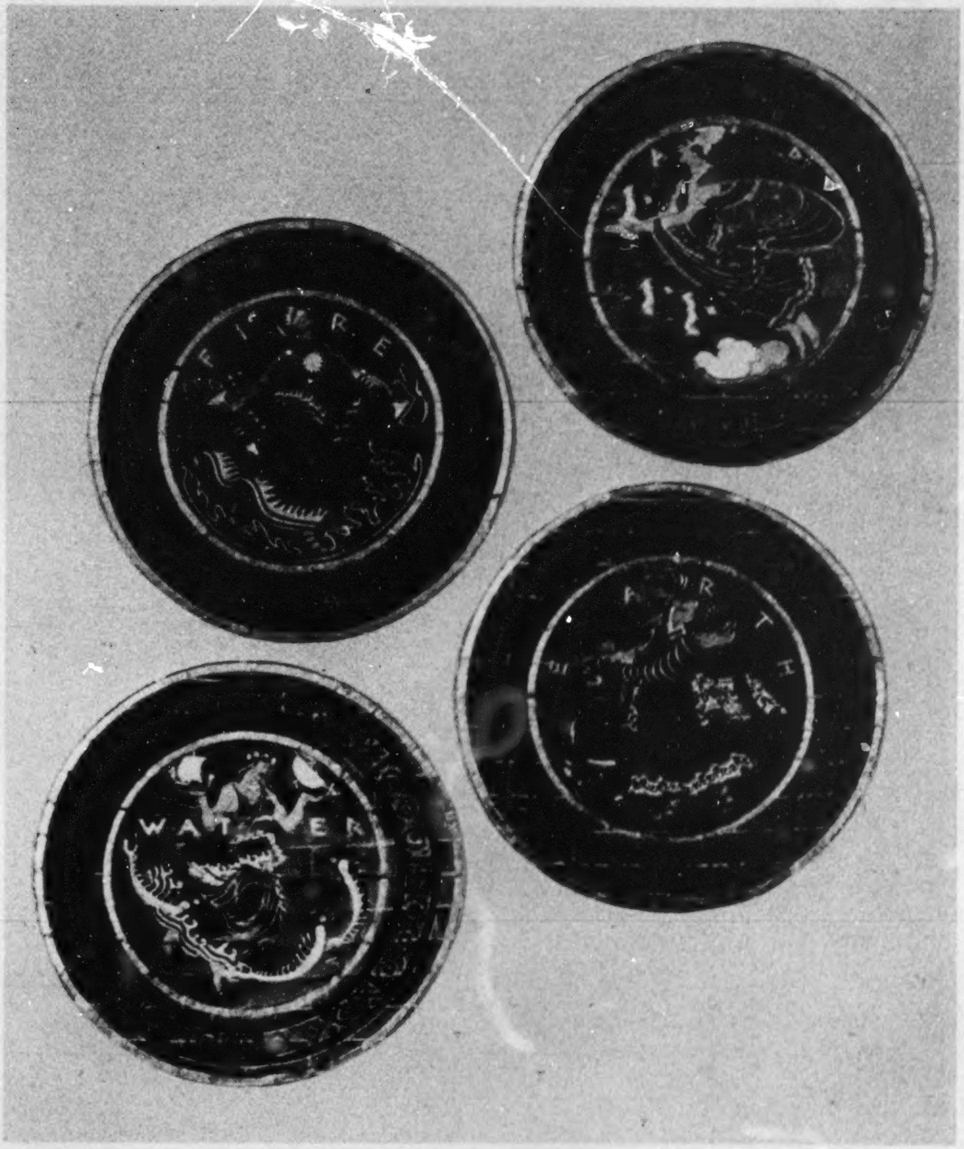
APPENDIXES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AIR
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WATER

Appendix A

On Potential Sources of Bias

Prospective members of a study committee are requested to complete this "bias" form whenever the committee may deal with matters involving value judgments as well as the evaluation of purely quantitative material.

• • •

Reports of appointed committees and other bodies of the National Academy of Sciences/National Academy of Engineering/Institute of Medicine/National Research Council which consider technical matters directly relevant to issues of public interest or policy frequently contain conclusions and recommendations that necessarily rest upon professional value judgments as well as upon quantitatively evaluated data.

When this is the case, some instances will arise in which it is inappropriate to appoint to membership an individual who has a substantial professional or financial interest that would be affected by the outcome of the deliberations. In other instances, however, it may be imperative that appointments be made in such a way as to represent a balance of interests or opinions known to be in conflict.

It is for these reasons that you are requested to complete the form on the reverse hereof, showing: (1) industrial or commercial affiliations over the last ten years, as an employee, director, officer, or consultant; (2) sources of research support over the last five years; (3) the names of companies in which you now hold financial interests in an amount exceeding $10,000 in market value, which also represent more than 10% of your current holdings.

More subtle is the question of other potential sources of bias, e.g., views or conclusions to which you are publicly committed, other than through formal publication in scientific or engineering journals, on matters within the purview of the group to which you are appointed. You are asked on the reverse hereof to indicate any such activities or commitments which, in your judgment, might reasonably appear to others as potentially compromising of your independence of judgment, and hence in some measure prejudicial to the work of the group on which you serve.

If, during your term of service, any of these conditions should change, a letter explaining the circumstances should be provided for the file.

Each of our committees and other similar bodies is asked to discuss the matter of potential sources of bias at its first meeting and once annually thereafter. On those occasions the chairman will share with the other members such information from these statements as may appear relevant. We shall treat the statements themselves as privileged to those of our offices whose proper business they are; the information given will not be made more widely available except under the most unusual circumstances, and then only with the approval of the individual to whom it pertains.

APPENDIX A

NATIONAL ACADEMY OF SCIENCES
INSTITUTE OF MEDICINE

NATIONAL ACADEMY OF ENGINEERING
NATIONAL RESEARCH COUNCIL

October, 1975

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BOARD, DIVISION, OR OFFICE

COMMITTEE

SUB-UNIT

NAME

PRESENT AFFILIATION

(Above lines to be completed by cognizant office before form is sent to appointee)

Please read statement on reverse side

1. INDUSTRIAL OR COMMERCIAL AFFILIATIONS DURING LAST TEN YEARS

   (a) *As an employee (state position)* (b) *As a Director or Corporate Officer*

   (c) *As a consultant*

2. SOURCES OF RESEARCH SUPPORT DURING LAST FIVE YEARS (other than employer)

3. COMPANIES IN WHICH YOU HAVE CURRENT FINANCIAL INTERESTS (Please list only holdings with market value in excess of $10,000 which also amount to more than 10% of your total investments. Please do not list actual amounts.)

4. ADDITIONAL INFORMATION (e.g., views expressed publicly relevant to matters within the purview of the group to which you are appointed, other than in formal publication in scientific or engineering journals; see fourth paragraph on reverse side.)

Date

Signature

This statement is privileged to those offices whose proper business it is. It will not be made more widely available except with the approval of the individual to whom it pertains.

Appendix B

Guidelines for Review of Reports

These guidelines, prepared by the Report Review Committee, are provided to all reviewers of NRC reports—whether they are reviewing for the involved Assembly or Commission or for the Report Review Committee.

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Every report from the Academy complex (NAS–NAE–NRC–IOM), before it is issued, is reviewed by a group other than the authors. The purpose of the review is to help authors make their report as accurate and clear as possible and to provide greater assurance that the authoring committee and the institution are creditably represented by the reports published in their name. Whereas the reports are prepared by carefully constituted committees of experts, the review group consists of scientists, physicians, and engineers usually not specializing in the subject matter of the report.

It is their task to read reports thoughtfully and critically, to make appropriate comments and suggestions, and to identify in advance possible difficult or troublesome questions that are pertinent and that might otherwise be asked in embarrassing ways after the report is made public. The reviewing group may disagree with the authors and is free to press its views upon them as strongly as it wishes, but it must bear in mind that the authors must subscribe to the final formulation. Reports are issued in the name of the Academy and over the signature of the authors. Thus, both have responsibility for the final product. In this connection, it should be noted that, throughout the

Academy complex, the review process is monitored by the Report Review Committee.

Here are some key questions that reviewers should bear in mind when reading draft(s):

1. Is the report clear and concise?
2. Are the data adequate for the argument presented?
3. Are the uncertainties in the data recognized?
4. Is the report complete?
5. Is the report fair?
6. Could the "conflict of interest" issue harm the report?
7. Are political questions handled with circumspection?
8. How does the report relate to other published material on the same subject?

These questions, as expanded below, may not all apply to a particular report. Also, the reviewing panel need not be concerned with detailed editorial comments, which can be handled more efficiently by the Editorial Office at the time of editing of the final draft.

1. *Is it clear and concise?*

Is there an adequate introduction or summary? Is the task of the study stated clearly and are the conclusions adequately developed and explicitly formulated? Is the argument and exposition put in such a way as to be intelligible to the intended audience? Are the style and level of the report consistent throughout or, if not, are the parts intended for different audiences clearly distinguished? Are technical terms adequately explained? Do figures and tables really support inferences made from them in the text? Does each have an essential function? Are there places at which additional figures or tables would clarify the text? Are there statements that are ambiguous or may be misunderstood? Is there too much detail or needless repetition? Is there excess jargon? Are there arguments that should be recast and made more cogent? Are there illogical or incomplete arguments?

In short, do the authors make a clear case for their conclusions from the standpoint of a less involved or less committed audience?

2. *Are the data adequate for the arguments presented?*

Does the report meet high standards of scientific and technical excellence? Are the appropriate questions analyzed quantitatively? Does the report present adequate data for the problems considered? Do the conclusions follow from the data?

3. *Are the uncertainties in the data recognized?*

Does the report adequately present any uncertainties intrinsic to the data? Are systematic errors noted? Are appropriate statistical methods used? Are the possible influences of these uncertainties on the conclusions suitably noted?

4. *Is it complete?*

Is the report as complete as is needed for the purpose? Are important relevant subjects omitted? Is some pertinent experimental evidence omitted or inadequately represented? Are some topics slighted and others overemphasized? If so, does this bias the report as a whole?

Does the report add something new or is it just a restatement of well-known facts?

Finally, does the title fit the contents?

5. *Is it fair?*

Are the viewpoints of others fairly presented? If there are strong criticisms of institutions or individuals, are they necessary to the case at hand? If so, are they non-pejorative and adequately documented? If the government policy or action is attacked, is the policy or action in question adequately explained and is the criticism well formulated?

6. *Conflict of interest*

Is material that might appear to be special pleading appropriately supported? Are recommendations being made that will benefit a particular institution (including NAS–NAE–NRC–IOM) or group of institutions with which the authors are connected? Does the analysis in the report reveal or suggest bias or favoritism?

7. *Are political questions handled with circumspection?*

Are there recommendations to the government that may not be appropriate coming from the Academy as an institution? If these are proposals to government agencies, are they based on adequate scientific and technical grounds? If there are suggestions for legislation, do they address the substantive general problem, leaving the details to appropriate political institutions?

8. *How does the report relate to other published material on the same subject?*

Does it add enough that is new in the way of hard information or perspective to be worth the effort invested in it?

Conclusions:

Virtually none of the questions listed above is such that simple yes or no answers will be obtained from reading the draft report. Exercise of sensitive judgment is essential. The authors should be given the benefit of the doubt unless the possibility exists that the report will not creditably represent the writers of the report or the National Academy of Sciences.

The Press and Publicity

In the event that a reviewer is questioned by reporters on a document he had reviewed, he is free to discuss the report only after he has determined that the report has been released to the public. However, he should refrain from references to earlier drafts and should keep in mind that the deliberations of the review panel are internal to the Academy complex and, thus, remain privileged.

Appendix C

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APPENDIX C

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Appendix D

Reports of the NRC Published in 1975[*]

ASSEMBLY OF BEHAVIORAL AND SOCIAL SCIENCES

Assessing Demand for Outdoor Recreation. (Committee on Assessment of Demand for Outdoor Recreation Resources; 123 pp.; available from the U.S. Department of the Interior, Bureau of Outdoor Recreation, 18th and C Streets, N.W., Washington, D.C. 20240.)

Compensation Formula for Hearing Loss. (Committee on Hearing, Bioacoustics, and Biomechanics; 4 pp.; limited number of copies available from the committee.)

Protecting Individual Privacy in Evaluation Research. (Committee on Federal Agency Evaluation Research; 131 pp.; available from the NAS Printing and Publishing Office; ISBN 0-309-02406-4; $7.00.)

Toward an Understanding of Metropolitan America. (Social Science Panel on the Significance of Community in the Metropolitan Environment, Advisory Committee to the Department of Housing and Urban Development; 193 pp.; available from Canfield Press, 805 Montgomery Street, San Francisco, California 95033; ISBN 0-06-385492-9; $3.95.)

Visual Elements in Flight Simulation. (Committee on Vision; 70 pp.; limited number of copies available from the committee.)

[*] Reports from the NAS Printing and Publishing Office are available from the Printing and Publishing Office, National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington, D.C. 20418. For National Technical Information Service (NTIS) reports, write to the National Technical Information Service, Springfield, Virginia 22161. For reports available from a committee, write to the committee, National Academy of Sciences. Other reports are available from the sources noted. Prices and availability subject to change.

ASSEMBLY OF ENGINEERING

Building Effective Minority Programs in Engineering Education. (Committee on Minorities in Engineering; 135 pp.; limited number of copies available from the committee.)

Information and Data Exchange for Ocean Engineers: An Approach to Improvement. (Panel on Marine Engineering Information and Data Exchange, Marine Board; 85 pp.; limited number of copies available from the board.)

Mining in the Outer Continental Shelf and in the Deep Ocean. (Panel on Operational Safety in Marine Mining, Marine Board; 119 pp.; available from the NAS Printing and Publishing Office; ISBN 0-309-02405-6; $6.25.)

New Experiments in Research and Development Incentives. (Ad Hoc Panel on Experimental R&D Incentives; 24 pp.; limited number of copies available from the assembly.)

Practical Applications of Space Systems. (Space Applications Board; 67 pp.; *Supporting Paper 1: Weather and Climate,* Panel on Weather and Climate, 25 pp.; *Supporting Paper 2: Uses of Communications,* Panel on Uses of Communications, 46 pp.; *Supporting Paper 3: Land Use Planning,* Panel on Land Use Planning, 55 pp.; *Supporting Paper 4: Agriculture, Forest, and Range,* Panel on Agriculture, Forest, and Range, 47 pp.; *Supporting Paper 5: Inland Water Resources,* Panel on Inland Water Resources, 77 pp.; *Supporting Paper 6: Extractable Resources,* Panel on Extractable Resources, 22 pp.; *Supporting Paper 7: Environmental Quality,* Panel on Environmental Quality, 56 pp.; *Supporting Paper 8: Marine and Maritime Uses,* Panel on Marine and Maritime Uses, 37 pp.; *Supporting Paper 9: Materials Processing in Space,* Panel on Materials Processing in Space, 30 pp.; *Supporting Paper 10: Institutional Arrangements,* Panel on Institutional Arrangements, 46 pp.; *Supporting Paper 11: Costs and Benefits,* Panel on Costs and Benefits, 75 pp.; *Supporting Paper 12: Space Transportation,* Panel on Space Transportation, 31 pp.; *Supporting Paper 13: Information Services and Information Processing,* Panel on Information Services and Information Processing, 29 pp.; *Supporting Paper 14: Technology Support,* Panel on Technology Support, 12 pp.; limited number of copies available from the board.)

A Review of Short Haul Passenger Transportation. (Committee on Transportation; 147 pp.; available from the NAS Printing and Publishing Office, ISBN 0-309-02445-5; $6.25.)

Safety of Outer Continental Shelf Petroleum Operations: Third Report of the Review Committee. (Review Committee on Safety of Outer Continental Shelf Petroleum Operations, Marine Board; 12 pp.; limited number of copies available from the board.)

Safety of Outer Continental Shelf Petroleum Operations: Fourth Report of the Review Committee. (Review Committee on Safety of Outer Continental Shelf Petroleum Operations, Marine Board; 25 pp.; limited number of copies available from the board.)

ASSEMBLY OF LIFE SCIENCES

Amputee Clinics in the United States and Canada. [Eighth Edition]. (Committee on Prosthetic-Orthotic Education and the Committee on Prosthetics Research and Development, Division of Medical Sciences; 81 pp.; limited number of copies available from the Committee on Prosthetics Research and Development.)

Animals for Research: A Directory of Suppliers of Laboratory Animals, Animals from Nature, Fluids, Tissues and Organs [Ninth Edition]. (Institute of Laboratory Animal Resources, Division of Biological Sciences; 194 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–02326–2; $4.50.)

Communication and Sensory Aids for the Deaf–Blind. Report of a workshop held at the National Center for Deaf–Blind Youths and Adults, November 29–30, 1973. (Committee on Prosthetics Research and Development, Division of Medical Sciences; 15 pp.; limited number of copies available from the committee.)

Epidemiology of Lumbar Disc Lesions in the Military in World War II. (Medical Follow-up Agency, Division of Medical Sciences; 11 pp.; limited number of copies available from the agency.)

Follow-up Studies of World War II and Korean War Prisoners: Morbidity, Disability, and Maladjustments [Part 22]. (Medical Follow-up Agency, Division of Medical Sciences; 22 pp.; limited number of copies available from the agency.)

Food Chemicals Codex [Second Edition]. (Committee on Food Protection, Food and Nutrition Board, Division of Biological Sciences; 44 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–01949–4; $20.00.)

Genetic Screening: A Study of the Knowledge and Attitudes of Physicians. (Committee for the Study of Inborn Errors of Metabolism, Division of Medical Sciences; 89 pp.; limited number of copies available from the committee.)

Genetic Screening: Procedural Guidance and Recommendations. (Committee for the Study of Inborn Errors of Metabolism, Division of Medical Sciences; 53 pp.; limited number of copies available from the committee.)

Genetic Screening: Programs, Principles, and Research. (Committee for the Study of Inborn Errors of Metabolism, Division of Medical Sciences; 388 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–02403–X; $6.00.)

Lung Cancer Mortality in World War I Veterans with Mustard-Gas Injury: 1919–1965. (Medical Follow-up Agency, Division of Medical Sciences; 7 pp.; limited number of copies available from the agency.)

Mobility for Spinal-Cord-Impaired People. Report of a workshop held at Los Amigos Hospital, Downey, California, February 22–24, 1974. (Committee on Prosthetic–Orthotic Education and the Committee on Prosthetics Research and Development, Division of Medical Sciences; 180 pp.; limited number of copies available from the Committee on Prosthetics Research and Development.)

Nickel: Medical and Biological Effects of Environmental Pollutants. (Panel on Nickel, Committee on Medical and Biologic Effects of Environmental Pollutants, Division of Medical Sciences; 277 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–02314–9; $10.75.)

NIH *[National Institutes of Health] Rodent Repository.* (Committee on Maintenance of Genetic Stocks, Institute of Laboratory Animal Resources, Division of Biological Sciences; 38 pp.; limited number of copies available from the institute.)

Nonhuman Primates: Usage and Availability for Biomedical Programs. (Committee on Conservation of Nonhuman Primates, Institute of Laboratory Animal Resources, Division of Biological Sciences; 122 pp.; limited number of copies available from the institute.)

Nutrition and Fertility Interrelationships: Implications for Policy and Action. (Subcommittee on Nutrition and Fertility, Committee on International Nutrition Programs, Food and Nutrition Board, Division of Biological Sciences; 60 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–02341–6; $4.50.)

Oral Contraceptives and Nutrition. (Committee on Nutrition of the Mother and the Preschool Child, Food and Nutrition Board, Division of Biological Sciences; 3 pp; limited number of copies available from the board.)

Population and Food: Crucial Issues. (Committee on World Food, Health and Population, Division of Biological Sciences; 50 pp.; limited number of copies available from the division.)

Preoperative Irradiation for Carcinoma of the Rectum and Rectosigmoid Colon: Report of a National Veterans Administration Randomized Study. (Medical Follow-up Agency, Division of Medical Sciences; 6 pp.; limited number of copies available from the agency.)

Preoperative Radiotherapy for Colorectal Cancer. (Medical Follow-up Agency, Division of Medical Sciences; 8 pp.; limited number of copies available from the agency.)

Prevention of Microbial and Parasitic Hazards Associated with Processed Foods: Guide for the Food Processor. (Committee on Food Protection, Food and Nutrition Board, Division of Biological Sciences; 166 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–02345–9; $5.75.)

Prosthetics and Orthotics Research Reference Catalogue, Volume Two: Article Numbers 2501 to 3064. (Committee on Prosthetic–Orthotic Education and the Committee on Prosthetics Research and Development, Division of Medical Sciences; 352 pp.; available from the NAS Printing and Publishing Office, ISBN 0–309–02402–1; $27.00.)

Relationship of Cell Type and Lymph Node Metastasis to Survival After Resection of Bronchial Carcinoma. (Medical Follow-up Agency, Division of Medical Sciences; 5 pp.; limited number of copies available from the agency.)

Report of the Colombian and Peruvian Primate Censusing Studies. (Committee on Conservation of Nonhuman Primates, Institute of Laboratory Animal Resources, Division of Biological Sciences; 104 pp.; limited number of copies available from the institute.)

Research in Zoos and Aquariums. A symposium held at Houston, Texas, October 6–11, 1973. (Institute of Laboratory Animal Resources, Division of Biological Sciences; 215 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–02319–X; $7.25.)

The Solitary Pulmonary Nodule: Ten-Year Follow-up on Veterans Administration–Armed Forces Cooperative Study. (Medical Follow-up Agency, Division of Medical Sciences; 6 pp.; limited number of copies available from the agency.)

Standards for Cardiopulmonary Resuscitation and Emergency Cardiac Care. (Committee on Emergency Medical Services, Division of Medical Sciences, and American Heart Association; available from the American Heart Association, 2007 I Street, N.W., Washington, D.C. 20006.)

Summary Statement of the Asilomar Conference on Recombinant DNA Molecules. (Organizing Committee for the International Conference on Recombinant DNA

Molecules, Division of Medical Sciences; 13 pp.; limited number of copies available from the division.)

Survey of Analgesic Drug Prescribing Patterns. (Committee on Problems of Drug Dependence, Division of Medical Sciences; 274 pp.; available from the Drug Abuse Council, Inc., 1828 L Street, N.W., Washington, D.C. 20036.)

Synthetic Substitutes for Opiate Alkaloids: A Feasibility Study. (Committee on Problems of Drug Dependence, Division of Medical Sciences; 77 pp.; available from the Drug Abuse Council, Inc., 1828 L Street, N.W., Washington, D.C. 20036.)

Three-Dimensional Shape Sensing and Reproduction of Limbs and Limb Remnants. A report of a conference held at the University of British Columbia, Vancouver, Canada, October 18, 1973. (Committee on Prosthetics Research and Development, Division of Medical Sciences; 56 pp.; limited number of copies available from the committee.)

ASSEMBLY OF MATHEMATICAL AND PHYSICAL SCIENCES

Assessment of the Impact of World Data Centers on Geophysics. (Committee on Data Interchange and Data Centers, Geophysics Research Board; 35 pp.; limited number of copies available from the committee.)

Catalog of United States Contributions to the International Hydrological Decade 1965–1975. (U.S. National Committee for the International Hydrological Decade; 255 pp.; limited number of copies available from the committee.)

Compatability Guide for Adjacent Loading of Bulk Liquid Cargoes. (Committee on Hazardous Materials; 21 pp.; limited number of copies available from the committee.)

Environmental Impact of Stratospheric Flight: Biological and Climatic Effects of Aircraft Emissions in the Stratosphere. (Climatic Impact Committee, 348 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–02346–7; $8.00.)

Establishment of a Solar Energy Research Institute. (Solar Energy Research Institute Committee; 50 pp.; available from the Office of Public Affairs, Technical Information Center, U.S. Energy Research and Development Administration, Oak Ridge, Tennessee 37830.)

Fellowship and Research Opportunities in the Mathematical Sciences, 1975–1976. (Office of Mathematical Sciences; 43 pp.; limited number of copies available from the office.)

Fire Hazard Classification of Chemical Vapors Relative to Explosion-Proof Electrical Equipment: Report IV. (Committee on Hazardous Materials; 42 pp.; limited number of copies available from the committee.)

Interim Report of the Panel on Atmospheric Chemistry. (Panel on Atmospheric Chemistry, Climatic Impact Committee; 8 pp.; limited number of copies available from the committee.)

Long-Term Worldwide Effects of Multiple Nuclear-Weapons Detonations. (Committee to Study the Long-Term Worldwide Effects of Multiple Nuclear Weapons Detonations; 213 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–02418–8; $8.50.)

Matrix of Electrical and Fire Hazard Properties and Classifications of Chemicals. (Committee on Hazardous Materials; 36 pp.; limited number of copies available from the committee.)

Nuclear Science: A Survey of Funding, Facilities, and Manpower. (Committee on Nuclear Science; 130 pp.; limited number of copies available from the committee.)

Nuclear Techniques in Hydrology: Current Status and Prospective Uses. (U.S. National Committee for the International Hydrological Decade; 43 pp.; limited number of copies available from the committee.)

Opportunities and Choices in Space Science, 1974. (Space Science Board; 187 pp.; limited number of copies available from the board.)

Opportunities for Permafrost-Related Research Associated with the Trans-Alaska Pipeline System. Report of a workshop held at Scottsdale, Arizona, March 19–22, 1975. (Committee on Permafrost, Polar Research Board; 37 pp.; limited number of copies available from the board.)

Products from Jojoba: A Promising New Crop for Arid Lands. (Committee on Jojoba Utilization; 30 pp.; limited number of copies available from the Office of Chemistry and Chemical Technology.)

Proposed National Resource for Computation in Chemistry: A User-Oriented Facility. (Office of Chemistry and Chemical Technology; 51 pp.; limited number of copies available from the office.)

Report on United States Antarctic Research Activities, 1974–75, and United States Antarctic Research Activities Planned for 1975–76. (Polar Research Board; 90 pp.; limited number of copies available from the board.)

System for Classification of the Hazards of Bulk Water Transportation of Industrial Chemicals. (Committee on Hazardous Materials; 42 pp.; limited number of copies available from the committee.)

Understanding Climatic Change: A Program for Action. (Panel on Climatic Variation, Committee for the Global Atmospheric Research Program; 239 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–02323–8; $6.50.)

United States Space Science Program: Report to COSPAR *[Committee on Space Research].* Eighteenth Meeting, Varna, Bulgaria, June 1975. (Space Science Board; 90 pp.; limited number of copies available from the board.)

Views of the National Academy of Sciences Committee on Radio Frequencies Concerning Frequency Allocations for the Radio Astronomy Service in Preparation for the World Administrative Radio Conference—1979 [First Revision]. (Committee on Radio Frequencies; 24 pp.; limited number of copies available from the committee.)

COMMISSION ON HUMAN RESOURCES

Doctorate Recipients from United States Universities: Summary Report, 1974. (Commission on Human Resources; 27 pp.; limited number of copies available from the commission.)

Graduate School Adjustments to the "New Depression" in Higher Education. (National Board on Graduate Education; 96 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–02328–9; $4.75.)

Mutual Educational Exchange Program Under the Fulbright-Hays Act, 1976–1977: University Lecturing—Advanced Research. (Council for International Exchange of Scholars; 44 pp.; limited number of copies available from the council.)

Personnel Needs and Training for Biomedical and Behavioral Research. (Committee on a Study of National Needs for Biomedical and Behavioral Research Personnel; 84 pp.; limited number of copies available from the commission.)

Research Training and Career Patterns of Bioscientists: The Training Programs of the National Institutes of Health. (Committee on a Study of the Impact of the NIH Research Training Programs; 160 pp.; limited number of copies available from the Committee on the Study of National Needs for Biomedical and Behavioral Research Personnel.)

Science Development: An Evaluation Study. Technical Report Number 4. (National Board on Graduate Education; 182 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–02329–7; $5.75.)

Science Development, University Development, and the Federal Government. Report Number 4. (Board on Graduate Education; 48 pp.; limited number of copies available from the board.)

COMMISSION ON INTERNATIONAL RELATIONS

Arid Lands of Sub-Saharan Africa; Staff Progress Report, September 1973–June 1974; *Staff Final Report,* July 1974–December 1974; *Appendices to the Staff Final Report.* (Advisory Panel on Arid Lands of Sub-Saharan Africa, Board on Science and Technology for International Development; *Staff Progress Report,* 118 pp.; *Staff Final Report,* 36 pp.; *Appendices,* 277 pp.; limited number of copies available from the commission.)

Childhood in China. Report of the American Delegation on Early Childhood Development in the People's Republic of China. (Committee on Scholarly Communication with the People's Republic of China; 241 pp.; available from the Yale University Press, 92A Yale Station, New Haven, Connecticut 06520; ISBN 0–300–01917–3; $12.50 cloth; $3.95 paper.)

"Earthquake Research in China." (Report of the American Seismology Delegation. Frank Press, *et al., Eos—Transactions, American Geophysical Union* 56: 838–881, 1975) (Cosponsored by the Committee on Scholarly Communication with the People's Republic of China of the National Academy of Sciences, the Social Science Research Council, and the American Council of Learned Societies.)

Herbal Pharmacology in the People's Republic of China. (Committee on Scholarly Communication with the People's Republic of China; 269 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–02438–2; $8.00.)

An International Centre for Manatee Research. Report of a workshop held in Georgetown, Guyana, February 7–13, 1974. (Cosponsored by the National Academy of Sciences of the United States of America, the National Research Council of Guyana, and the International Development Centre of Canada; 34 pp.; limited number of copies available from the Board on Science and Technology for International Development.)

Language and Linguistics in the People's Republic of China. Based on Accounts of the Linguistic Delegation, October 16–November 13, 1975. (Committee on Scholarly Communication with the People's Republic of China; 168 pp.; available from the University of Texas Press, Austin, Texas 78712; ISBN 0-292-7415-6; $9.50 cloth, $3.95 paper.)

Natural Products for Sri Lanka's Future. Report of a workshop held in Colombo, Sri Lanka, June 2–6, 1975. (Cosponsored by the National Academy of Sciences of the United States of America and the National Science Council of Sri Lanka; 53 pp.; limited number of copies available from the Board on Science and Technology for International Development.)

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